SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

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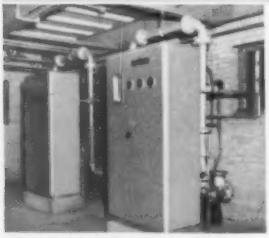

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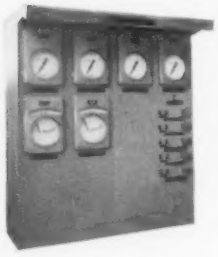

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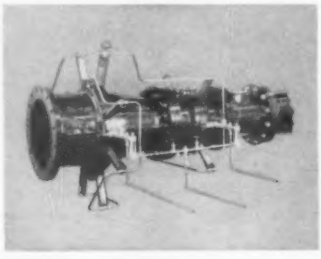

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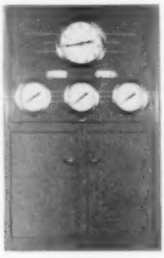

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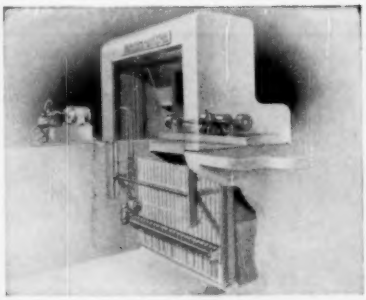

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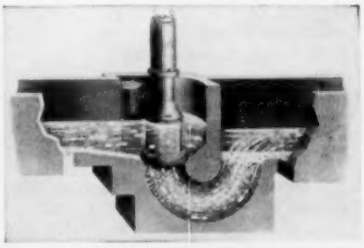

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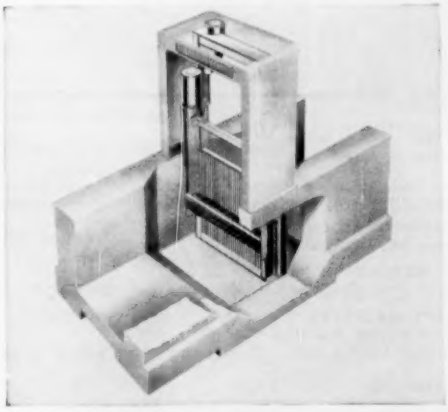

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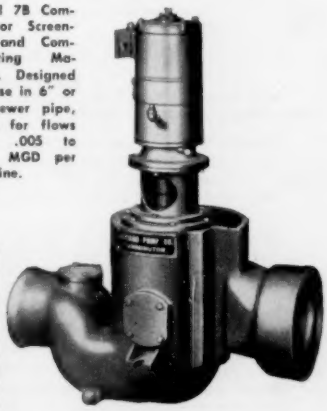

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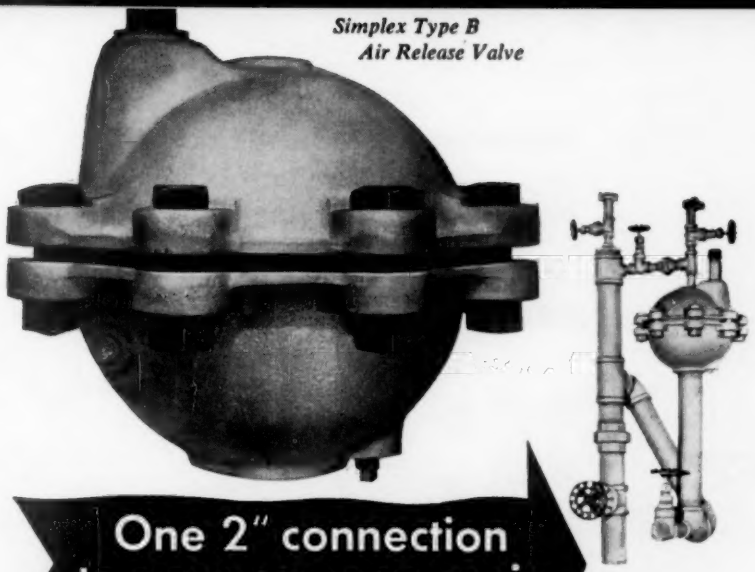

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Texas Water and Sewage Works Assn.	Texas A & M College College Station, Tex.	Mar. 3–8, 1957
New Jersey Sewage and Industrial Wastes Assn.	Traymore Hotel Atlantic City, N. J.	Mar. 13–15, 1957
Arkansas Water & Sewage Conf.	Marion Hotel Little Rock, Ark.	Mar. 18–20, 1957
Louisiana Conference on Water Supply and Sewerage	Univ. of Louisiana Baton Rouge, La.	Mar. 20–22, 1957
Montana Sewage and Industrial Wastes Assn.	Rainbow Hotel Great Falls, Mont.	Apr. 4, 1957
Arizona Sewage and Water Works Assn.	Maricopa Inn Mesa, Ariz.	Apr. 4–6, 1957
Kansas Sewage and Industrial Wastes Assn.	Broadview Hotel Wichita, Kans.	Apr. 10–12, 1957
California Sewage and Industrial Wastes Assn.	San Diego, Calif.	May 1–4, 1957
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Institute of Sewage Purification	Margate, England	June 17–21, 1957

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SYRACUSE, New York
Water Div., Dept. of Engineering
TORONTO, Ontario
The Consumer's Gas Co. of Toronto
TROY, New York
Department of Public Works
UTICA, New York
City of Utica, Board of Water Supply
WHEELING, West Virginia
City of Wheeling Water Department
*WILLIAMSPORT, Pennsylvania
Williamsport Municipal Water Authority
WILMINGTON, Delaware
Wilmington Water Department
WINCHESTER, Virginia
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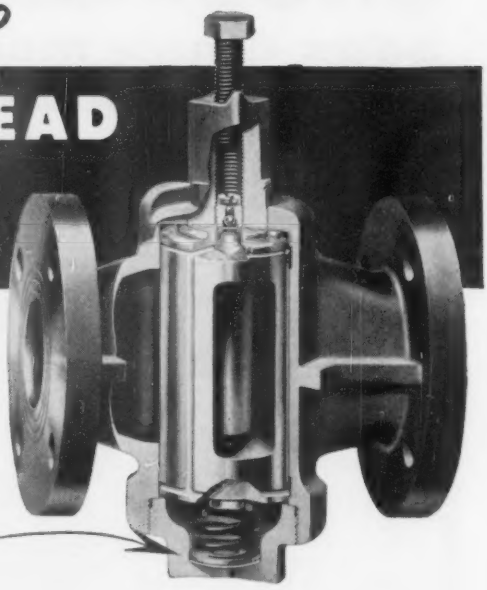
No. 4* of 12 REASONS WHY
YOU SHOULD BUY AND USE
LOW-PRICED
HOMESTEAD *Lubricated* PLUG VALVES



* SPRING TORSIONAL STRESS RELIEVED BY TEFLON WASHER

Low friction Teflon washer permits spring to turn with plug. This means that less maintenance and longer life are assured, because the spring is subjected to compression only.

This is only **one reason why you should buy and use low-priced** HOMESTEAD LUBRICATED PLUG VALVES.

HERE ARE ALL TWELVE

1. Reinforced Teflon stem seal.
2. Completely controlled high-pressure lubricant system prevents sticking.
3. 100% pipe area or venturi patterns.
4. No spring torsional stress.
5. No mechanical adjustments.
6. Quick operation—Quarter turn to open or close.
7. Extremely close tolerance between sealing surfaces.
8. Triple head-seal with lubricant and Teflon packing ring.
9. Plug floated on Teflon washer.
10. Leak-proof double-ball and lubricant-sealed check valve.
11. Full-threaded screw assures clean lubricant.
12. Extruded lubricant shows when system is full.

FOR CATALOG AND COMPLETE DETAILS
MAIL COUPON TODAY

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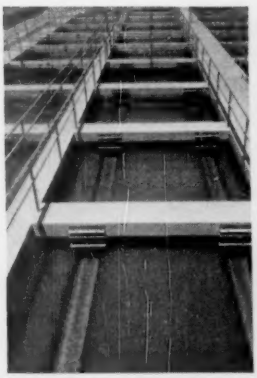
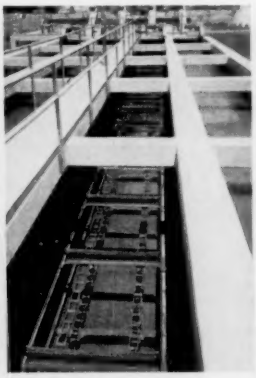
VALVE MANUFACTURING COMPANY
"Serving Since 1892"
P. O. Box 48 Coraopolis, Pa.

Without obligation, send Reference Book 39—Section 5 on HOMESTEAD LUBRICATED PLUG VALVES.

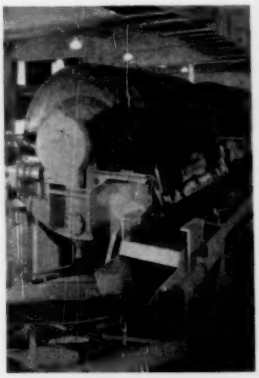
NAME_____ TITLE_____
COMPANY_____
ADDRESS_____
CITY_____ STATE_____



PRE-AERATION increases efficiency of 20 tanks equipped with sludge collectors. Air floats grease, flocculates solids and adds dissolved oxygen to the effluent.



FOUR LINK-BELT grit collectors slow sewage velocity to 1.25 fps . . . and remove grit from lighter solids that remain in suspension.



SLUDGE CAKE is conveyed from vacuum filters by Link-Belt belt conveyors. It is used as "Soil Conditioner" by the City Park, nurseries and home gardeners.

How Sacramento effectively controls ODOR - - POLLUTION - - DISPOSAL

LINK-BELT pre-aeration and sludge removal equipment satisfies rigid water purity standards

SINCE 1949, Sacramento's population and industry have increased 50%. To stop odors and water pollution in the Sacramento River, the city recently installed a new sewage treatment plant equipped with Link-Belt grit collecting and washing equipment, sludge collectors and skimming equipment, and belt conveyors for handling the dewatered sludge. The equipment was included in specifications drawn up by the engineering office of Clyde C. Kennedy, Consulting Engineers.

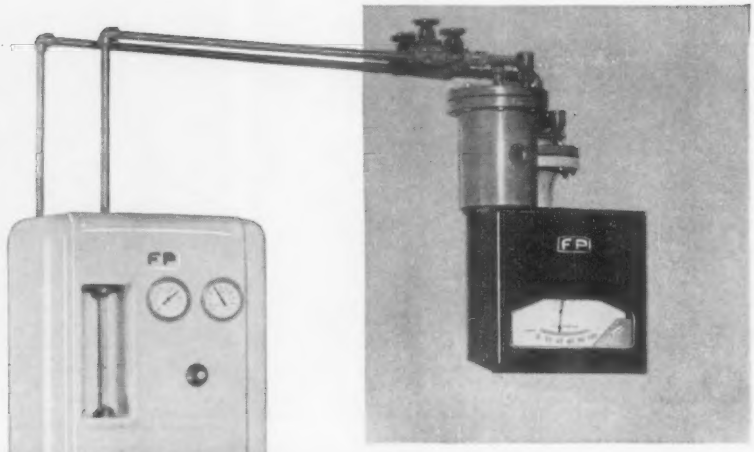
Link-Belt's complete line of equipment and broad engineering experience provide low-cost, efficient water, sewage and waste treatment for municipalities and industries throughout the country. A call to your nearest Link-Belt office will put you in touch with our sanitary engineers who will work with your consultants and chemists.

14,220

LINK-BELT

SANITARY ENGINEERING EQUIPMENT

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants and Sales Offices in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville, N.S.W.; South Africa, Springs. Representatives Throughout the World.



Continuous visual record assures efficient use of Chlorine

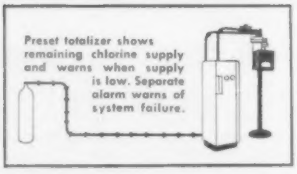
EFFICIENT USE OF CHLORINE puts money in your pockets. Comparison of chlorine and main line flow records provides a continuous safeguard against wasted chlorine or insufficient dosage by continuously monitoring the accuracy of the system.

This recording system is readily adaptable to most chlorinators of all manufacturers.

A simple screwdriver adjustment permits field synchronization of the flow recorder with the interchangeable capacity of the chlorinator. Indicators, totalizers, transmitters and high-low alarms are available for use in this F&P Chlorine Flow Recording System. These functions may be located remotely by the use of F&P pneumatic or electric transmission systems.

Every part is completely corrosion resistant. Magnetic coupling eliminates the need for trouble-making pressure tight bearings.

Write today for complete information or detailed proposals and quotations to Fischer & Porter Co., 1116 Fischer Road, Hatboro, Pa.



FP FISCHER & PORTER CO. Hatboro, Pa.
COMPLETE PROCESS INSTRUMENTATION

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COMPLETE LINE to Meet Your Exact Needs

Including many Exclusive Developments

Utilize our many years of experience in the development and manufacture of municipal and industrial waste treatment equipment. Our staff of engineers is ready to cooperate with consulting and operating engineers in suggesting the process of treatment and type of equipment best suited to individual needs.

BIO-ACTIVATION—exclusive system combines best qualities of trickling filter and activated sludge. *Bulletin 259B.*

MECHANICALLY CLEANED SCREENS AND GRINDER—with intermittent automatic control. *Design data in Technical Supplement MS.*

GRIT CHANNELS—exclusive Camp Chamber design and Regulator permit easy and instant variation in velocity. *Design data in Technical Supplement CR.*

GRIT SETTLERS—with conveyor, elevator, and exclusive Hydrowash unit which removes grease and organic matter from grit. *Bulletin 249B.*

GREASE FLOTATION UNIT—removes grease and oils, produces simultaneous aeration and agitation, and oxidizes objectionable odors. *Bulletin 260B.*

SEWAGE AND SLUDGE PUMPS—horizontal and vertical pumps in wide range of sizes, capacities and heads—including cutting type primary sludge pumps, enclosed impeller type sewage pumps, single vane impeller type sewage pumps and recirculation pumps. **Send for Bulletins.**

SLUDGE COLLECTORS—for rectangular and circular tanks . . . flight type and helicoid cross conveyors . . . sludge valves. *Bulletin 253B and Technical Supplement TV.*

AERATORS—downflow mechanical air diffusion type provides thorough and adjustable oxygenation and circulation of liquor. *Bulletin 265A.*

JET AERATION—exclusive method produces an unprecedented rate of oxygen absorption. *Bulletin 265A.*

ROTARY DISTRIBUTORS—reaction and positive drive types with exclusive trouble-free oil seal. *Design data in Technical Supplement RD.*

DOWNFLO FLOCCULATION UNIT—for slow mixing and flocculation of chemicals in sewage treatment processes. *Design data in Technical Supplement PF.*

Send for informative bulletins listed above.

Inquiries on new installations or improvements of existing plants will receive prompt attention.

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Pumping, Sewage Treatment, and Water Purification Equipment
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Fairfax County, Va. orders COILFILTERS for 3 more plants!

Continued confidence is the finest proof of product performance. In 1954 the Westgate sewage treatment plant in Fairfax County, Virginia, designed by Massey Engineers, placed their two 200 sq. ft. Coilfilters in operation. When equipment was purchased for three more Fairfax County plants in 1956, it was only natural that Coilfilters should be included.

The Little Hunting Creek and Dogue Creek plants, designed by R. Stuart Royer and Associates, will each contain an 85 sq. ft. "package" unit. The Upper Pimmit Run plant, designed by Massey Engineers, will include a 150 sq. ft. Coilfilter and auxiliaries.

Alexander Potter Associates are Consultants to the County of Fairfax.

KOMLINE-SANDERSON ENGINEERING CORPORATION

Peapack, New Jersey

Manufacturers of the **COILFILTER** *... the modern sludge vacuum filter*

Combined MILITARY-CIVIC CENTER Adds Permanent Health Insurance

During World War II, the Air Force built a flight base near the Georgia town of Warner Robins. Almost overnight, it became a bustling city . . . and it has continued to expand ever since. Warner Robins is already the civic center for 33,000 people.

The city is providing "health insurance" for its future with *permanent* Vitrified Clay Pipe. More than 96,000 additional feet of Clay Pipe in diameters up to 30 inches was recently installed, together with a treatment plant that can be expanded to serve a community twice its present size. Warner Robins, following the lead of many growing cities, is set for the future—with the *only* sewer pipe that *never wears out.*

Mayor: W. T. Giles
City Engineer: C. M. Franklin
Architects and Engineers: Vinson & Company
Chief Engineer: R. M. Breen
Resident Engineer: W. R. Peck
Contractor and General Supt.: Howard T. Barry

The Public *KNOWS* Clay Pipe Is Best

Vitrified CLAY PIPE

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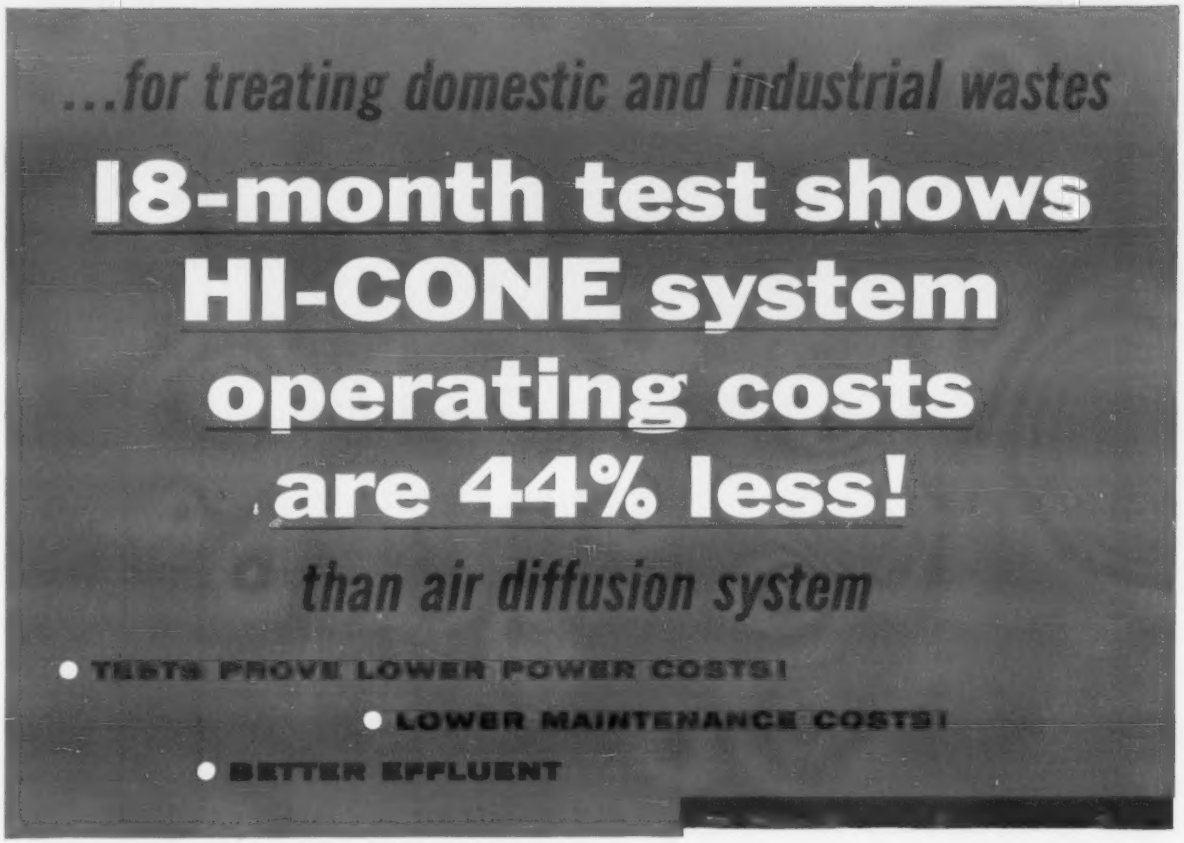
...for treating domestic and industrial wastes
18-month test shows
HI-CONE system
operating costs
are 44% less!
than air diffusion system
• TESTS PROVE LOWER POWER COSTS!
• LOWER MAINTENANCE COSTS!
• BETTER EFFLUENT

In the selection of sewage treatment equipment, the two most important factors are operating cost and effluent quality.

These figures from the annual report of the Manchester, England, Rivers Department, *prove* the superiority of the Hi-Cone! They're based on the operation of activated sludge plants (including a Hi-Cone System and a diffused air system) under strictly comparable conditions over a period of 18 months. Manchester is a pioneer in treatment by the activated sludge process, having first conducted experiments and tests in 1913.

Hi-Cone's power consumption was lower! Horsepower demand per million gallons treated per 24-hour day for the Hi-Cone System was 34.9% lower than the air diffusion system.

Hi-Cone's total operating costs were lower! Relative costs per million gallons treated were 42.1% lower than the air diffusion system.

Hi-Cone's effluent was better! The B.O.D. reduction was 26% greater; the suspended solids removal was 5% greater than the air diffusion system.

Use this coupon to ask for detailed information

Please send the following descriptive literature on the Hi-Cone:

☐ Cost and operating reports ☐ Report of article, "U. S. and British engineers agree on the Hi-Cone System"

☐ Hi-Cone engineering data

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. . . manufacturers of:
centrifugal pumps • pneumatic sewage ejectors • distributors • clarifiers • mechanical aerators • digesters

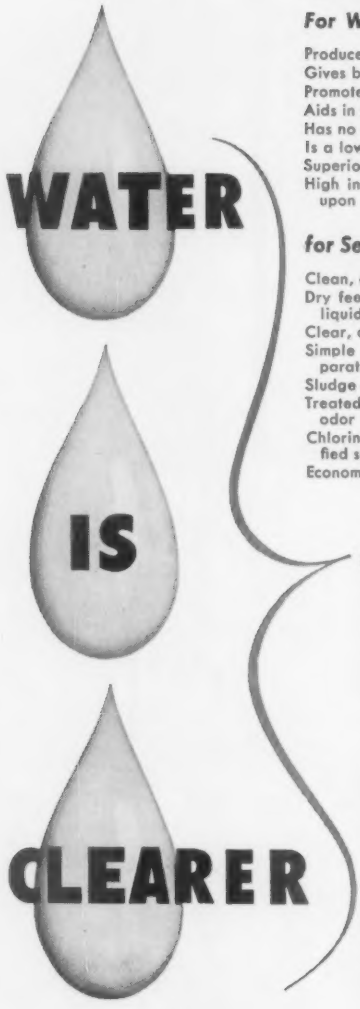
First Choice Coagulant of Most American Municipalities

For Water Treatment

Produces crystal-clear water
Gives better floc formation
Promotes better settling and longer filter runs
Aids in reduction of tastes and odors
Has no chlorine demand
Is a low-cost coagulant
Superior in tests against other coagulants
High in quality. Its constant uniformity can be depended upon

for Sewage Treatment

Clean, easy to handle
Dry feeds well or dissolves readily for solution feeding; liquid alum also available in many areas
Clear, colorless effluents are possible
Simple application. Requires only low-cost feeding apparatus and minimum attention
Sludge digests readily
Treated digested sludge dries quickly with a minimum of odor
Chlorine consumption is cut due to lower demand of clarified sewage
Economical to use



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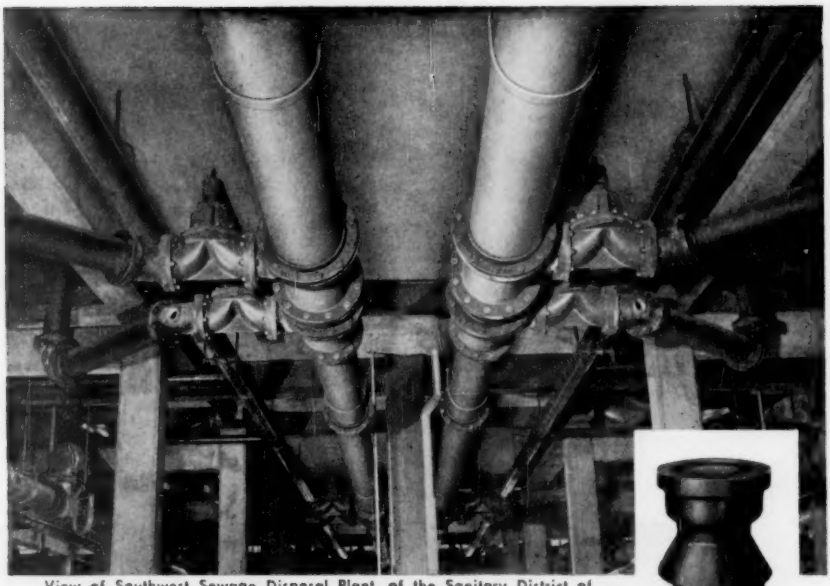


View of Southwest Sewage Disposal Plant, of the Sanitary District of Chicago, Stickney, Illinois . . where Clow Cast Iron Pipe was furnished to meet exact requirements.

Clow cast iron pipe, fittings, valves and specials for sewage plant replacements or new installations

• James B. Clow & Sons with their many years of experience as manufacturers of Cast Iron Pipe and Special Castings for Filtration and Sewage Disposal Plants know the difficult piping problems that continually face the sanitary engineer. Clow shops are completely equipped with the latest machinery. Clow's skilled workmen will produce pipe and specials to your exact specifications. Pipe can be furnished flange and flange, flange and bell, flange and plain end or with mechanical joint and plain end—in sizes 3 through 24 inches in laying lengths up to 18 feet.

CLOW (Threaded) Cast Iron Pipe

Clow also manufactures (threaded) Cast Iron Pipe in steel pipe sizes 3 through 10 inches which has the same outside diameter as common steel pipe. This pipe can be cut, threaded and fitted on the job with ordinary tools of the piping trade.

JAMES B. CLOW & SONS ☆

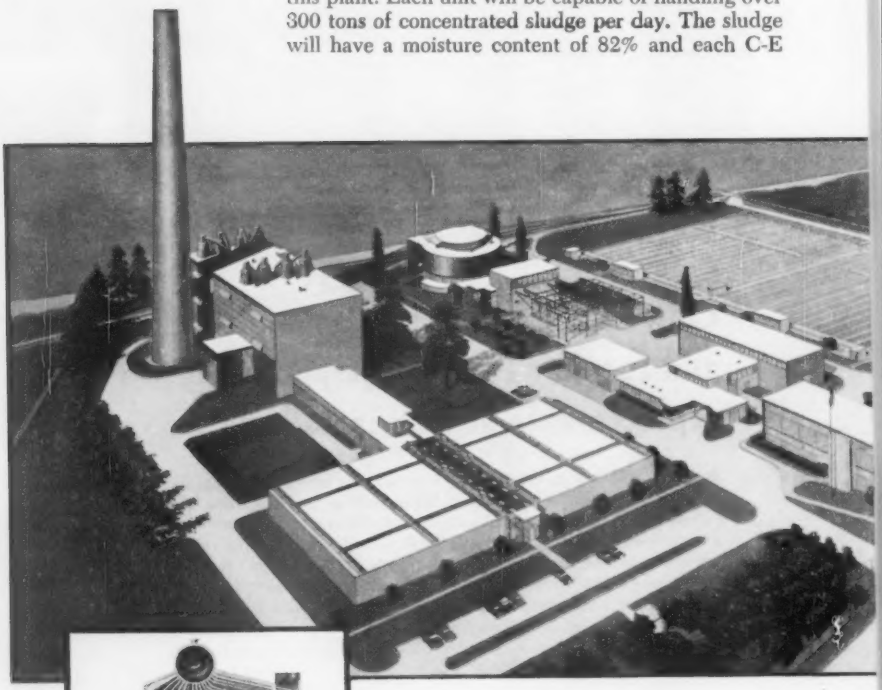
201-299 North Talman Avenue • Chicago 80, Illinois

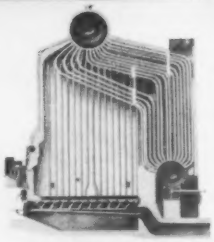
Subsidiaries:
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Oskaloosa, Iowa

Pittsburgh selects for sewage

Pittsburgh's projected one-hundred-million-dollar sewage treatment system will serve a total of seventy communities having an equivalent population of 1,500,000. More than sixty-three miles of new sewers will be laid to feed raw sewage to the hub of the system—the seventeen-million-dollar treatment plant to be located at Woods Run in the City of Pittsburgh.

Four C-E Raymond Flash Drying and Incineration Units will comprise the sludge disposal system at this plant. Each unit will be capable of handling over 300 tons of concentrated sludge per day. The sludge will have a moisture content of 82% and each C-E





Two C-E spreader stoker-fired boilers, Type VU-10, will provide the steam used to heat sludge in the concentration tanks, and to heat the plant.

The Pittsburgh Disposal Plant
J. F. Laboon, *Executive Director and Chief Engineer*
Metcalf and Eddy, *Consulting Engineers*

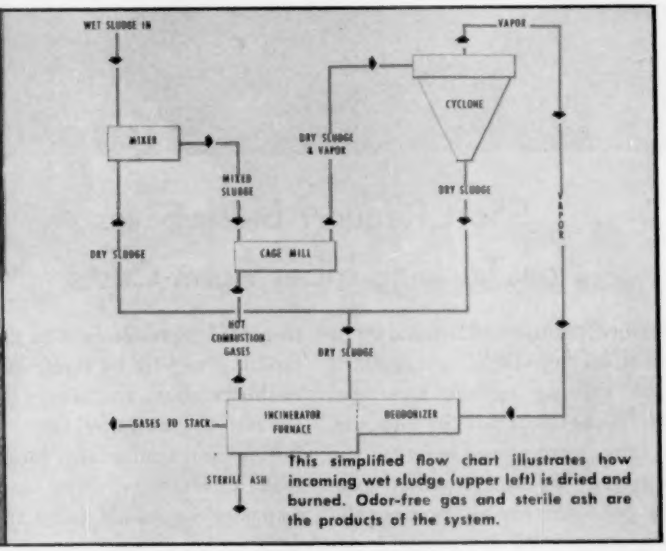
Incoming sewage will be pumped to the screens and aerated grit chambers and thence flow to the preaeration and settling tanks at far right. The solids will be pumped to the sludge concentration tanks (left foreground) where they will remain for five days. From there the sludge will be pumped to the incinerator building (left background) where it will be dried and burned. The incinerator building will also contain the two C-E boilers.

C-E Raymond
sludge incineration

Flash Drying and Incineration Unit will be capable of burning more than 55 tons of dry solids per day while evaporating more than 250 tons of water. Each C-E Raymond Unit will be equipped with a Deodorizing System which will free the moisture-laden combustion gases of objectionable odors. In addition, each of the four incineration systems will incorporate equipment for the control of fly ash.

Throughout the country, the C-E Raymond Flash Drying and Incineration System is achieving an ever-wider measure of popularity. In fact, *more filter cake is dried and/or burned by the C-E Raymond System than by all other systems combined.*

If you are considering new sewage treatment facilities, investigate *the modern method* of sludge disposal. C-E Raymond specialists will be happy to work with you and with your consultants. No obligation, of course.



This simplified flow chart illustrates how incoming wet sludge (upper left) is dried and burned. Odor-free gas and sterile ash are the products of the system.

COMBUSTION ENGINEERING

RAYMOND DIVISION

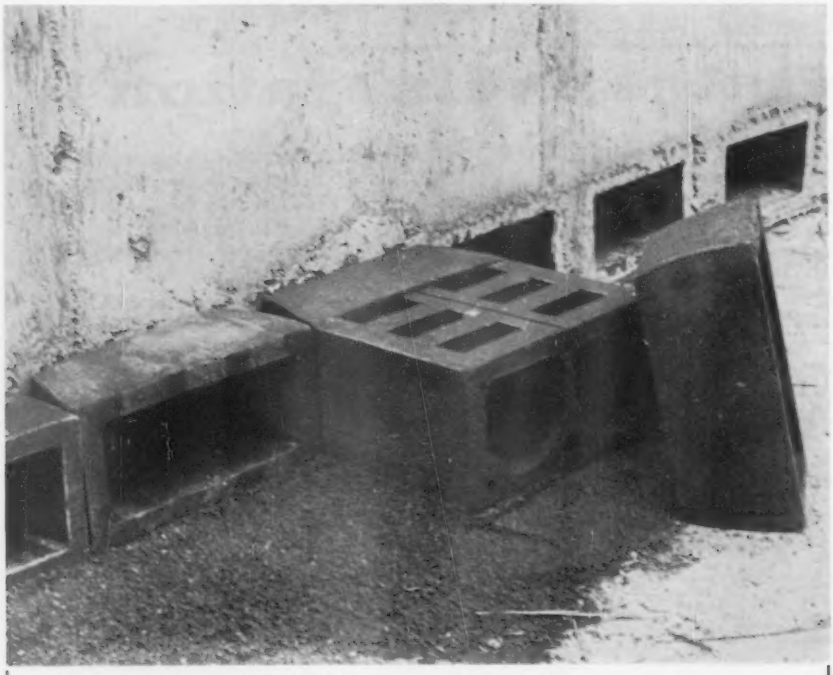
1315 North Branch Street, Chicago 22, Illinois

C-E

B-934A

Eastern Office: 200 Madison Ave., New York 16, N.Y. • Western Office: 510 W. Sixth St., Los Angeles 14, Calif.

ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL



Short Reducer Block Saves on Trickling Filter Form Costs

At Oxford, Ohio, an additional 99-ft. by 48-ft. rectangular filter was added to the existing sewage treatment plant. Lengths of 5-in. by 8-in. tile, 9-in. long, were placed between the reinforcing rod and standard prefabricated forms used in pouring the 9-in. concrete wall. No special forming was necessary to accommodate reducers protruding through the forms. Short reducers, 5-in. by 10-in., tapering to 5-in. by 8-in., were used as shown above to channel the effluent into the wall opening.

Bosco Filter Underdrain Block is all-shale, unglazed, vitrified block, and surpasses the ASTM C159 specifications in every requirement. Prices for estimating and design information will be gladly furnished.

BOSCO

The Bowerston Shale Company
P.O. Box 81
Bowerston, Ohio

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Standard Sluice Gates

Everything is standardized . . . all component parts. This applies to more than 300 types and sizes of Chapman Standard Sluice Gates. In this way, Chapman can meet *your* specifications at the lowest possible costs. These standardized parts are interchangeable. There's nothing hit or miss about the installation . . . no expensive matchmarking or field alterations. Everything is fitted perfectly at rock bottom cost. Even in use, these gates guard your dollars. The standardized parts are easy to replace . . . easy to fit. It's easy to keep your sluice gates in ideal working condition without expensive repair or service.

What's your requirement? Is it high or low head, seating or unseating pressures, large or small water area? Do you want manual, hydraulic or electric motor operation? Just name it. Chapman has the answer . . . sluice gates to meet your needs, standardized, every one.

Why not write for our Catalog 25-A, now?

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INDIAN ORCHARD, MASS.

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for the small community

It, too, can have the Best!

Morse Boulger Incinerator serving Lucas & Hunt Village, St. Louis, Mo.

The old-fashioned refuse dump—no matter how distantly located from the town—is still an eyesore, a health menace and a nuisance. Haulage to it and bulldozing (which should be done anyway) cost money.

Morse Boulger, while serving very large cities with high tonnage incineration, has never neglected the small community. It, too, is entitled to the best in incineration . . . which Morse Boulger Engineers can provide.

Have your consulting engineer get in touch with us about your requirements. We have basic drawings all set up for several types of incinerators in a wide range of capacities. We can expedite the plan you need.

MORSE BOULGER DESTRUCTOR CO.

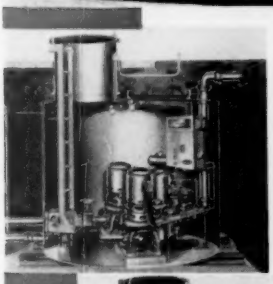
80-E 5th AVENUE • NEW YORK 11, N. Y.

Smith & Loveless

BUILDS FIVE (5) SEWAGE LIFT STATIONS FOR INDIANOLA, MISSISSIPPI

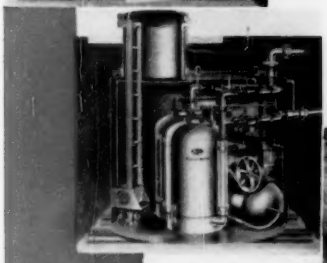
When bids were received for a sewer system at Indianola, Mississippi the cost of five (5) concrete lift stations exceeded the available funds.

To reduce the cost of these stations the consulting engineers, Ewin Engineering Corporation of Mobile, Alabama, prepared new plans and specifications for factory-built lift stations as manufactured by Smith & Loveless, Inc.



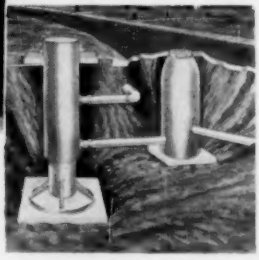
The Indianola lift stations recently installed are of both pump and ejector types as follows:

ONE—8′ diameter duplex pump station with 600 G.P.M. pumps.



TWO—8′ diameter "Way-O-Matic" duplex pneumatic ejector stations with 100 G.P.M. ejectors.

ONE—9′-6″ diameter "Way-O-Matic" duplex pneumatic ejector station with 200 G.P.M. ejectors.



ONE — 4′ diameter S & L "Mon-O-Ject" single pneumatic ejector station with 40 G.P.M. ejector and standby motor, compressor and controls.

For job recommendations, complete specifications and drawings — all part of the latest edition of the 100 page Smith & Loveless lift station Data Manual.

Hundreds of cities are reducing costs with Smith & Loveless "proven quality" lift stations.

WRITE DEPARTMENT 30

S&L

Smith & Loveless, Inc.

P. O. BOX 8172 • KANSAS CITY, MISSOURI

MANUFACTURING PLANT: MERRIAM, KANSAS

REPRESENTATIVES IN PRINCIPAL CITIES

Infiltration-proof AMVIT*JOINTED CLAY PIPE gives you lowest cost of sewer line in place

Longer, stronger pipe with plastic mechanical joint speeds installation, saves labor

Amvit jointed clay pipe produces professional results with minimum effort. The joint is on the pipe, delivered to the job ready to use. No other materials such as caulking, joint compound, hot-pots, or ladles are needed to make the Amvit joint. It takes just a few seconds to push the pipe together and the line is complete.

Field tests on the more than 60 installations completed show that Amvit prevents ground water infiltration. This results in sizable savings in both pumping and treatment plant costs. Amvit is a compression type joint on the ball and socket principle. Nothing can enter the line after it is complete.

Amvit jointed clay pipe, in sizes 4" through 24", together with all fittings is available for immediate delivery in the Northeast and Central States.

For more information, write or call American Vitrified Products Company, National City Bank Building, Cleveland, Ohio, or our office nearest you.

The Amvit Joint is made of a plastic material with rubber-like characteristics. Like the pipe, the joint will withstand the most severe underground conditions. Amvit Joint is furnished on all fittings.

*T. M. Registered. Patents Pending

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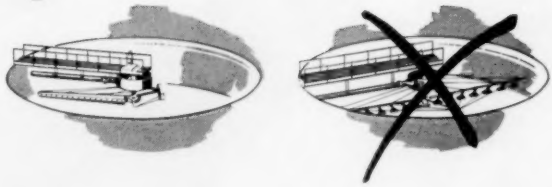

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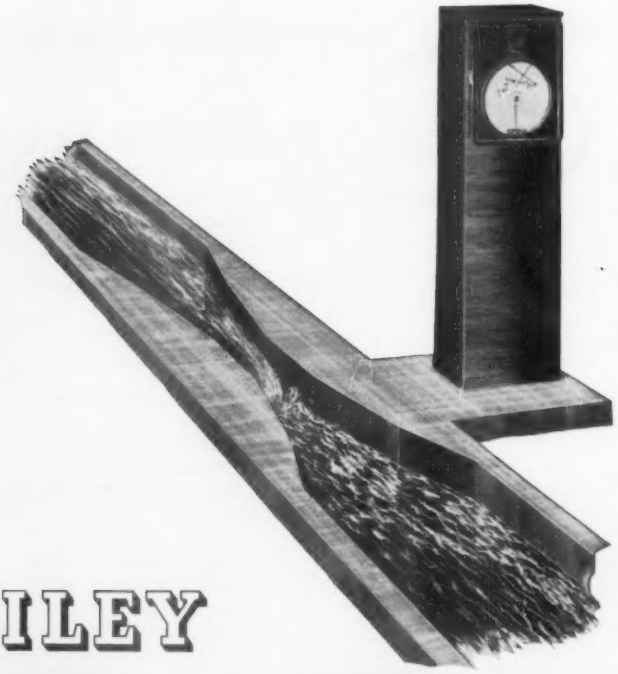

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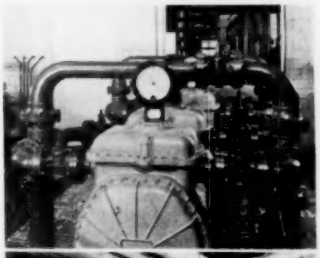

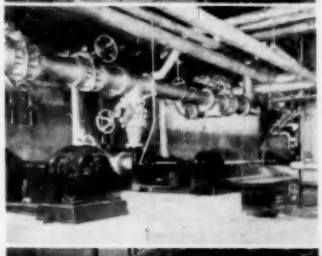

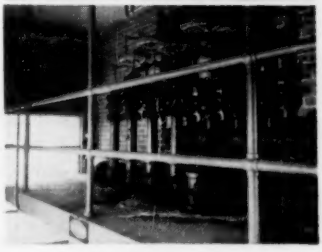

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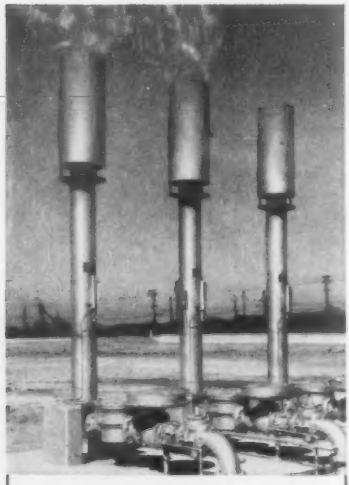

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

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Ralph E. Fuhrman, *Editor*, 4435 Wisconsin Ave., N.W., Washington 16, D. C.
Dr. F. W. Mohlman, *Advisory Editor* Donald P. Schiesswohl, *Assistant Editor*
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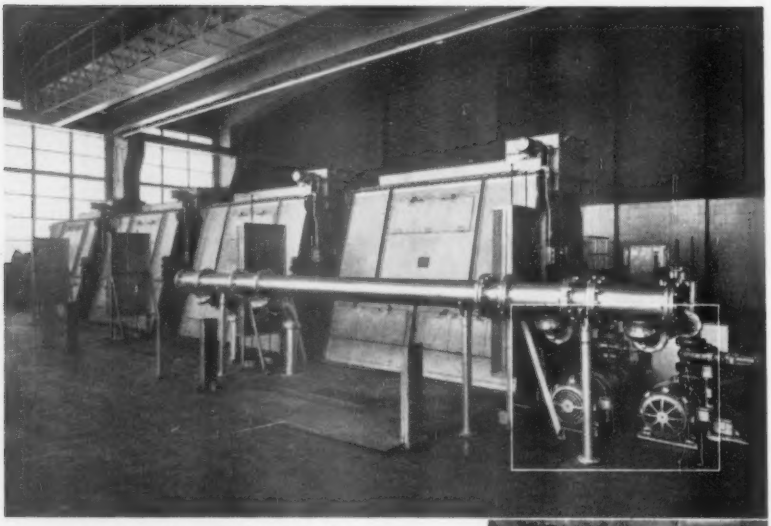
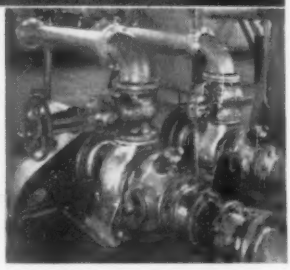


General view of screen room at Hyperion with Type S Screens at left and Disintegrators at right.

Screenings Handling Made Easy at Los Angeles Hyperion...



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Sewage Works

INTERMITTENT SAND FILTERS AND THEIR BIOLOGY

By Wilson T. Calaway

Assistant Research Professor, Department of Civil Engineering, University of Florida, Gainesville, Fla.

A recent report of research on sand filters (1) mentioned the renewal of interest that this method of sewage treatment is experiencing in Florida. The rapid growth of towns and cities in Florida has frequently extended residential areas far beyond the reach of municipal sewers. The development of small outlying communities and somewhat isolated subdivisions has made the cost of extending trunk sewers prohibitive. High water tables have in many cases necessitated the rejection of the septic tank-subsurface drain field even as a temporary expedient. The need for new homes has forced land developers to find a solution to the sewerage problem and sand filters are finding increased use under these circumstances. Multi-unit motels and trailer courts have also found that this is a feasible solution to their sewage treatment problems as have hotels and other businesses.

Sand filters have several features which recommend them for small installations. Most important of these are:

1. Septic tanks or small Imhoff tanks can be used to precede the filter.
2. Little or no mechanical equipment is required.
3. Skilled labor is not required for operation.
4. Maintenance is almost negligible.
5. Head losses may be kept at a minimum.
6. Flying insects are virtually negligible.
7. The effluent is clear and sometimes sparkling.
8. There is no secondary sludge to handle.
9. Bacterial removal is usually sufficient to reduce the chlorination problem to a minimum.

These reasons should interest many other community areas in this form of sewage treatment, especially in other sections of the South and in the Southwest where conditions are similar to those in Florida, and where material and land areas are readily available. Sand filters also have real possibilities for use in small industrial installations for handling certain types of wastes.

It would be a mistake, however, to imply that as a treatment method, sand filters are without faults. Among the general difficulties encountered are:

1. A large land area is needed, 20 times as much as for an equivalent trickling filter (not including the secondary tank for the trickling filter).
2. The effect of weather on the operation is greater than for other types of treatment.
3. Satisfactory sands are not always readily available.
4. Weeds grow luxuriantly on the beds and, therefore, frequent weeding is required.
5. A surface mat sometimes develops and requires scraping and removal.

6. Distribution of the sewage onto the beds is a difficult problem since the beds operate best if quickly and completely flooded (requiring careful design of the dosing mechanism and its appurtenances to insure almost instantaneous loading).

Most of these criticisms do not materially affect the use of intermittent sand filters for service of the type discussed in this paper.

Engineering Considerations

Sand for sewage filters should be practically pure silica as calcareous material will gradually dissolve or cement together or both. The effective size should be approximately 0.3 to 0.5 mm. Fine sands tend to clog quickly and cannot be loaded at reasonable rates. Larger diameter sands will provide treatment but distribution of the sewage on the filter bed becomes a considerable problem. The B.O.D. removal decreases somewhat as the size of the sand is increased; however, this may be compensated for by increasing the filter depth. Depth becomes more critical with larger sands, but loading rates may be higher (400,000 gal. per acre per day [g.p.a.d.] for sands with an effective size of 1 mm.). For sands with effective sizes of 0.3 to 0.5 mm., a filter bed depth of 30 in. is certainly sufficient for southern latitudes. Only a slight increase in treatment efficiency (probably 1 per cent with a filter 48-in. deep) is afforded by the greater depth, but the safety factor is increased. Uniformity coefficients should be as low as reasonably possible, as the interstices will be smaller with a sand having a high uniformity coefficient than with a sand having a low uniformity coefficient and the same effective size. However, sands with a uniformity coefficient between 3 and 4 have been used without apparent diminution of efficiency. Care must be exercised in placing the sand in the bed to maintain a uniform mixture, otherwise layers of fine sand may produce a localized build-up of organic matter with unsatisfactory results. If the sizes recommended are used, loading rates for areas in the southern United States may be 150,000 g.a.d. of settled sewage, preferably applied in two increments of 75,000 g.a.d. each. These rates should produce good results without clogging the bed or requiring frequent removal of the surface mat. Cold weather may require lower loading rates and hot dry weather often accentuates the accumulation of the surface mat by removing the moisture needed for the satisfactory biological action necessary to digest it. These filters may be adapted to subsurface installation if certain design changes are made and the loading rates are adjusted (2).

Theory of Operation

The high degree of treatment afforded by the sand filter and the simplicity of operation make the process attractive. In this regard, it should be noted that the Lawrence Experiment Station of the Massachusetts State Board of Health conducted a number of investigations on the sand filter method of treatment (3). It was these and other investigations that established a firm foundation for modern sanitary waste disposal practices. However, this work at Lawrence was most actively pursued around 1900, and the efficiency of the filter was evaluated by the determination of nitrogen fractions, the B.O.D. test being unknown at that time.

Evaluation of the effectiveness of intermittent sand filters in terms of the tests presently used, such as B.O.D., has been under study by the Sanitary Research Laboratory of the University of Florida. Determinations of the nitrogen fractions and solids have also been included in these studies in order that correlation with the earlier work might be possible and so that a fuller

understanding of the process might be obtained.

A casual acquaintance with intermittent sand filters might lead to the conclusion that the purification produced is entirely the result of mechanical removal of contaminants. However, the degree of B.O.D. removal is higher than might be expected by mechanical filtration alone, since about 22 per cent of the B.O.D. is in solution (4) and would not be removed by filtration. Furthermore, the filter assimilates the organic matter which is brought to it and such practices as back-washing are not used and even scraping is rarely required. It would appear, therefore, that biological action must exist. Examination of the sand will quickly bear this out, and such examination indicates the presence of large numbers of bacteria as well as protozoa and many multicellular organisms.

Sand Filter Biology

Bacteria

As in all other biological sewage treatment processes, the primary workers (or basic members of the ecology) are bacteria. These consist principally of the following six groups:

1. Zoogleal bacteria such as *Zoogloea ramigera.*
2. Aerobic spore formers such as *Bacillus cereus.*
3. Yellow bacteria such as *Flavobacterium aquatile.*
4. The so-called alkali-producing bacteria as represented by *Alcaligenes faecalis.*
5. The typical soil actinomycete, *Nocardia.*
6. The *Streptomyces.*

These are listed in approximate order of predominance, but the aerobic spore formers and yellow bacteria are about equal in number, with *Flavobacterium* predominating at one time and *Bacillus* at another. The zoogleal forms are several times as numerous as the other forms. *Zooglea ramigera* has been thoroughly investigated by Butterfield (5), Wattie (6) and others (7), who have shown the extensive ability and the importance of this group in sewage treatment processes. Both *Flavobacterium* and *Bacillus* are very active in the decomposition of organic nitrogen compounds and also absorb or destroy carbohydrates. *Bacillus* also has a marked ability to survive under anaerobic conditions and may attack any localized septic areas which develop in the filter bed. The presence of *Alcaligenes* is not well understood since it has a limited ability to use complex organic nitrogen and probably does not work on carbohydrates at all. These limitations may explain why the number of *Alcaligenes* is not great near the surface of the filter but increases in the deeper layers where the quantity of their food material has increased. It would seem that *Alcaligenes* is to a large extent dependent upon other bacteria to start the digestion of its food. Even though their numbers are small, the presence of *Nocardia* and *Streptomyces* is interesting. Soil bacteriologists state that these bacteria digest humus which is relatively low as an energy-yielding substance but which could cause clogging of the filter if it were not destroyed. Humus is actually a residue left by some types of bacteria and represents materials that were not usable by them.

Protozoa

Investigations of the protozoa of the sand beds indicate that certain species may be expected to be present most of the time. Dominant species may disappear at times only to reappear in the usual large numbers. This phenomenon is not easy to explain but there is indication that it may be caused, in part, by variations of temperature and moisture. The appearance and disappearance is most noticeable with the holotrich ciliates,

Colpoda and *Paramecium*, one or the other of which is usually the dominant ciliate of the filters. It is less noticeable with organisms of the colpidium group which include *Colpidium*, *Tetrahymena*, *Glaucoma* and *Leucophrys*, all of which are bacteria eaters of similar habits and significance.

The most constant ciliate in the filter is a hypotrich of the family *Oxytrichidae* but it is never present in very large numbers. Small peritrichs are frequently present and occasionally heterotrichs may be found. The latter are apparently washed in from anaerobic, or near anaerobic conditions up stream from the filter bed. Small flagellates also come from the primary tanks but conditions in the sand filter do not seem to be highly suitable and they do not multiply. The only flagellate that multiplies in the filter to an appreciable extent is the large euglenoid flagellate *Peranema*. The amoebae are more numerous in the sand filters than in any of the other secondary processes studied at the Sanitary Research Laboratory. These include both naked and shelled amoebae of many genera and species.

With the exception of certain amoebae, the protozoa are chiefly bacteria feeders. Most of them, particularly the holotrich ciliates, are important because they consume and flocculate the bacterial turbidity. Except for a few forms, their ability to disintegrate zoogleal masses and consume the bacteria which have become incorporated into these masses is not of sufficient importance to make marked inroads against accumulations of organic material in the interstices between the sand grains.

Metazoa

The possible accumulation of zoogleal masses, cellulose, humus, and similar materials in the interstices of the filter presents some interesting problems. The sand filter is unlike the trickling filter where the films either periodically or practically constantly slough off and are removed in secondary tanks. Research studies (8) have demonstrated very thoroughly the role of insects and their larvae, annelid worms, nematodes and other forms of higher animals, usually referred to as metazoa, in cutting loose the slimes of trickling filters in order that they may be flushed out. If such materials broke loose from the sand grains in an intermittent sand filter they would be filtered out again within a few inches. This is borne out by the fact that it is not necessary to follow sand filters with settling tanks.

While the trickling filter coagulates food material in the applied sewage and oxidizes considerable portions of such food, it also passes along to digestion units large quantities of the applied load. In contrast, the sand filter must assimilate by oxidation almost all the adsorbed and mechanically removed food. This fact alone probably will explain the large difference in loadings possible for the trickling filter as compared with the sand filter.

It has been mentioned previously that one of the residues from bacterial action is humus, which has a low value as an energy source and, therefore, is attacked by only a few bacterial forms. The small number of *actinomyces* and related forms is apparently not sufficient to handle the quantity of this material produced. It has also been noted that the protozoa are not highly effective in disintegrating the zoogleal masses, so these slimes conceivably could accumulate to the point of clogging the filter. Undoubtedly the growth of zooglea limits the quantity of sewage a filter will pass, but it is also true that without these organisms there would probably be little treatment.

It is in regard to the assimilation of these materials that the group of multicellular animals, the metazoa, are of interest. Metazoa found in the bed are annelid worms, flatworms, nematodes, rotifers, water mites, insects and

insect larvae. Other forms are also seen on rare occasions. Considering their size and number, the annelid worms are most significant. Like their close relative, the frequently-mentioned tubifid worm, these members of the bristle worm or oligochaet group have an insatiable appetite for sludges and slimes. They feed on the slimes of the bed, digesting and utilizing some of the material, keeping the bed open and accessible to oxygen. The castings they produce seem to be more readily worked on by other forms than was the original material, probably because it is porous, and bacteria and oxygen penetrate it readily. The quantity of more inert material of humus-like nature has been concentrated but has also been left as porous masses, the individual particles of which are finely divided and easily accessible for further microbial action.

Others of the metazoa group do similar work. However, it might be noted that some of the nematodes, water mites and flatworms prey on the oligochaets, thus keeping them in check and in an active state.

Summary

While filtration and adsorption play an important part in the purification of sewage in intermittent sand filters, biological oxidation is the most important action. Without the assimilation of filtered and adsorbed materials by biological agents, the filter beds would soon fail to function properly.

Bacteria, such as the zoogleal bacteria known to be important in the treating of sewage, as well as other forms, are the primary agents in the destruction of the organic substances. However, even these would contribute to clogging of the filter if they were not consumed by protozoa and metazoa. Of all the animal forms present, the oligochaet worms appear to be the most important in consuming sludges and slimes, thereby keeping the bed open and active.

The high degree of purification produced by intermittent sand filters is understandable when consideration is given to the large and varied biota present and the intimate contact between the biota and the sewage provided by this method of treatment.

Acknowledgments

The author is grateful for the helpful suggestions of Professors James B. Lackey, John E. Kiker, Jr., and Thomas deS. Furman, all of the College of Engineering, University of Florida. The biological findings summarized herein were supported by a research grant from the National Institutes of Health, U. S. Public Health Service.

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SOLVING METROPOLITAN CLEVELAND'S SEWERAGE NEEDS *

By George E. Flower

Commissioner of Sewage Disposal, Department of Public Utilities, Cleveland, Ohio

Cleveland has evolved from a community with wells and privies, to a metropolitan community with a water system that extends beyond the county borders, and a sewer system that is almost as extensive. Cleveland invested $60 million up to 1946 on its water system. During the 10 years from 1947 to 1956, inclusive, an additional $76 million was spent to continue and expand the water service. The cities of Berea and Chagrin Falls are the only areas in Cuyahoga County not served by Cleveland water. Water consumption has doubled, from 66 billion gallons in 1941 to an estimated 118 billion gallons in 1956. Raw water intake capacity is now at 455 m.g.d. Approximately 85 per cent of all the investments in the city's water system has been spent to meet the need of the rapid suburban growth.

The sewage plant improvement program also has kept pace with the needs of those districts using Cleveland facilities. The Department of Public Utilities builds, operates and maintains the sewage treatment plants, operating from revenues based on water consumption. The design and construction of the tributary sewers is a function of the Service Department and these expenditures are financed by general obligation funds. Since 1950, $11 million have been spent to provide complete treatment of the sewage received from the city's growing suburbs.

The City of Cleveland chose to extend its water system and sewage plant facilities to the suburbs. It could have chosen to bypass their needs. The city feels justly proud that its water and sewage expansion program has kept pace with the needs of a fast-growing area.

The population of Cuyahoga County has grown from the 1950 census count of 1,400,000 to 1,502,000 in 1954, and continues to increase at the rate of about 2 per cent per year.

Milestones

As early as 1896, the problem of protecting the water supply and disposing of storm and sanitary wastes resulted in the recommendation by a commission of engineers to build a system of combined sewers and a lake-front interceptor sewer along the shores of Lake Erie, to provide for a separation of 10 miles from the point of water intake and sewer outlet. The Easterly intercepting sewer has been in service since 1905, and has been followed by others as needed (Table I).

Major Construction

It is important to note that the commission of engineers recommended combined sewers for the main portion of the city, and that interceptors have been designed to receive not only the dry weather sewage flows, but also the first flush from street washings and continued contributions of storm water (up to rates approximately one and one-half times the average sewage flow), all excess amounts being discharged automatically into nearby watercourses by means of regulators or overflow weirs.

* Presented at 1956 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conf.; Cleveland, Ohio; June 13–15, 1956.

TABLE I.—Major Construction

Year Built	Item Constructed
1899–1916	Westerly intercepting sewer
1900–1932	Mill Creek intercepting sewer
1904–1913	Easterly intercepting sewer
1916–1933	Southerly intercepting sewer
1917–1933	Walworth Run intercepting sewer
1926–1939	Big Creek intercepting sewer
1922	Westerly sewage plant
1928	Southerly sewage plant
1938	Easterly sewage plant
1936–1937	Westerly digesters and vacuum filters
1938	Southerly digesters, incinerator and blower buildings
1947	Westerly overflow channel repair and grit dump
1951	Southerly overflow chambers and spillway conduit
1951	Southerly additional digesters and elutriation units
1952	Southerly comminutors, detritors and pre-settling tanks
1954	Southerly new and converted activated sludge facilities
1955–1956	Westerly new detritors and preaeration units
1955–1956	Southerly sludge pumping and heating, sewage sampling and scum trough improvements
1956	Southerly improvements to ash handling facilities

It is noted too, that the first public supply was taken from Lake Erie in 1856 (through an intake only 300 ft. in length), that early improvements in the quality of the water were obtained simply by extending new intakes farther and farther into the lake, and that treatment of the raw water was first provided by chlorination in 1911 and by filtration in 1918.

In passing, it might be well to note that the City of Cleveland supplies water to virtually all of Cuyahoga County and parts of Lake County, with the only other sources of public water being at Berea and Chagrin Falls (Figure 1).

Cleveland Location

The advantages accruing to Cleveland by virtue of its location on Lake Erie, at the mouth of the Cuyahoga River, are probably recognized, in one way or another, by a majority of its residents. For example, the lake and river are important to the city in the transportation, delivery and transfer of bulk commodities so essential to local industries; and the St. Lawrence Seaway is expected to open up new markets for import and export.

The lake also offers an economic and inexhaustible source of industrial and domestic water supply, and is valuable for recreational purposes. Moreover, the same lake and river are the only feasible points for final disposal of sewage plant effluents and industrial wastes, and for rainfall runoff and storm-water discharges. These seemingly incompatible uses of the lake water for water supply, recreation, and wastes disposal are great economic assets, but to retain them it is necesary that careful consideration be given to the location of sewage and industrial wastes, and to the locations for the dispersion of the sewage plant effluent.

Cleveland Sewage Facilities

The location of Cleveland is on a high coastal plain bordering Lake Erie with the exception of the Cuyahoga River valley. The sewer system is generally a combined gravity flow type with storm outlets to natural drainage courses, which have been mostly converted to large storm sewers. The city and surrounding suburbs served by the City of Cleveland and within the Cuyahoga watershed are divided by topography into four drainage districts with three sewage plants serving the three main districts.

The Cuyahoga River valley is the steel center of Cleveland. This low-level area is served in part by pumping stations, elevating sanitary wastes to higher level sewers which are tributary to the treatment plants.

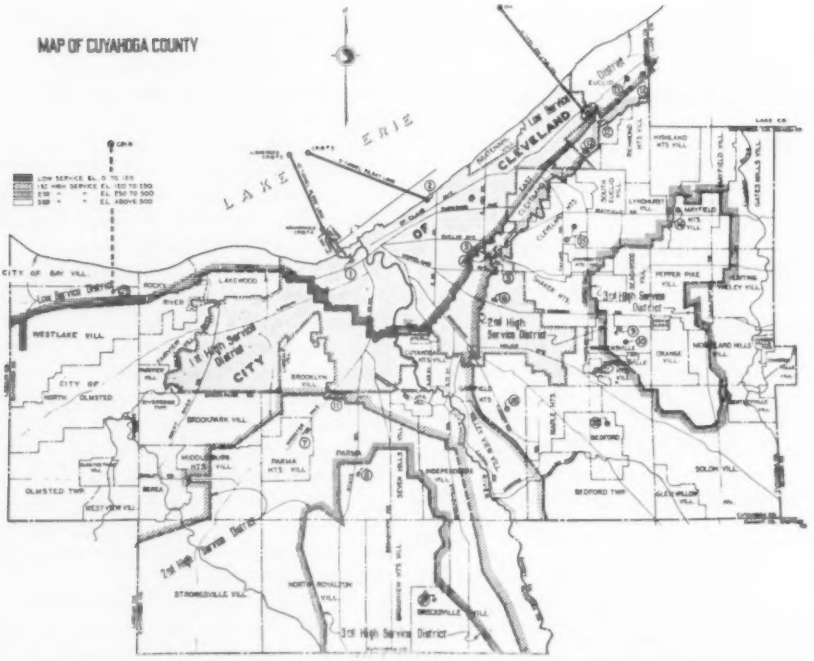

FIGURE 1.—Water supply plants and service districts, Cleveland, Ohio.

Plant Facilities

The Easterly sewage treatment plant is designed for 123 m.g.d. complete treatment by the activated sludge process. Features include bar grates, grit channels, comminutors, detritors, grease flocculation, primary settling tanks, aeration and final settling tanks, followed by chlorination in the bathing season. All solids, with the exception of grit, are pumped 13 miles to the Southerly site.

The Westerly sewage treatment plant is designed for 36 m.g.d. partial treatment. Features include bar grates, macerator, detritors, grease flocculation, Imhoff tanks, digestion, filtration, and incineration, with pre- and post-chlorination in the bathing season.

The Southerly sewage treatment plant is designed for 68 m.g.d. complete treatment by the activated sludge process. Features include bar grates, grit channels, detritors, comminutors, primary settling, aeration and final settling tanks, gas and dual-fuel engines providing compressed air. Sludge handling facilities at Southerly serve both the Easterly and Southerly plants, making this the largest single installation of its type ever built. Features include digestion, elutriation, filtration and incineration, with secondary digestion of supernatant.

Present Arrangements

The Department of Public Utilities does not derive any money from the general fund, but is self-sustaining. That is, all interest, fixed charges, operation, maintenance, and collection expense are derived from income from the sale of services of the light, water, and sewage treatment plants.

The three operating divisions are also separate indentities and are in themselves self-sustaining. The de-

partment pays its share for services of the other departments of the local government, such as law, finance, purchasing, etc. Rent is paid for the office space used in City Hall and the Lincoln Building, at a fairly high rate. Further limitations fixed by council legislation as to "free services" by the water and sewage division amount to a sizeable sum each year, but are partially compensated for by intangible benefits received.

The Division of Sewage Disposal treats the sewage received at the three Cleveland plants; namely, Easterly, Westerly and Southerly. However, this department does not build or maintain any sewers; but it does operate or subsidize three pumping stations.

Finance

Modernization of the original facilities has resulted in expenditures of nearly $11 million since 1950, in order to keep abreast of the demands for the sewerage service. Since 1938, all construction costs have been borne by revenue bonds. Prior to that date, more than $16 million were issued as general obligation bonds and the amortization of these bonds is still being paid from tax funds.

Billing

All residents of the City of Cleveland are billed for sewerage service (sewer rental charge) on the basis of the water consumption, the rate being a flat $0.25 per 1,000 cu. ft., with provision for exemption if the water is non-returnable to the sewer system.

A mutual agreement exists with the City of Lakewood, in which a portion of Lakewood tributary to the City of Cleveland is exchanged for Cleveland area tributary to Lakewood. This arrangement has worked quite well, as Cleveland has treated more total sewage than Lakewood.

A physical count of residents in Euclid and Cleveland is made each year to determine the charges to be made where several streets are tributary to each others' sewage treatment plants. This is an unsatisfactory method, as vast quantities of water from Euclid industries, not present when the 1927 agreement was made, have changed the picture and the equities involved are becoming harder to negotiate.

The City of Cleveland has a contract with the Cuyahoga County Board of Commissioners for those areas coming under the County Sewer District Law. The law was originally intended to provide storm sewers for unincorporated communities. The 15 sewer districts tributary to the City of Cleveland now include cities with as much as 65,000 population. The present contract expired as of May 1951, and a new contract is in process of negotiation.

Water accounts are classified as "master meter" or "direct service." In master meter suburbs, water is supplied at wholesale rates at the city line, where it is metered and supplied for distribution. The cities of Bedford, Cleveland Heights, East Cleveland, and Lakewood have such contracts.

The direct service suburbs are those in which Cleveland provides water meters, makes connections, and performs all the functions any other public utility would perform. These suburbs are charged $0.46 per 1,000 cu. ft. of water used. Most of these communities are under the county contract.

The villages of Newburgh Heights and Cuyahoga Heights receive "free sewage service" because of an original condition for granting an easement of a sewer more than 100 ft. underground. This is in effect a tax on the property owned by the City of Cleveland. The right to collect sewer service charges on industrial accounts is being contested, as it is contended that these accounts were not included in the meaning of "sanitary sewage."

TABLE II.—Population Distribution in Cleveland Sewer System Areas

Plant	Resident Population			Equivalent Population	
	Cleveland	Suburban	Total	Average Industrial	Total
Easterly	402,820	148,374	551,194	259,099	810,293
Southerly:					
1954	—[1]	—[1]	—[1]	—	—
1955	271,858	135,277	407,135	84,034	491,169
Westerly	218,231	10,341	228,572	82,340	310,912
Lakewood	56,457[2]	18,031[2]	66,798	0	66,798
Euclid[4]	—	46,510	—	—	—
Cleveland Totals	892,909	293,992	1,186,901	425,473	1,612,374

Per cent served in 1954 in Cuyahoga County: $\frac{1,186,901}{1,501,600} = 79.2$

Per cent Cleveland population: $\frac{892,909}{1,186,901} = 75.3$

Per cent suburban population: $\frac{293,992}{1,186,901} = 24.75$

[1] Populations are correct as of 1954; flows were not tributary for entire period 1954. See 1955 calculations for flow and strength in terms of B.O.D. and suspended solids for comparative purposes.

[2] Lakewood residents.

[3] Cleveland residents.

[4] Hilltop District only.

Complete treatment is being given to the normal dry weather flow of 22 political subdivisions in Cuyahoga County to the extent that these respective sewers are tributary to the sewer system. To be more specific, all sewage reaching the sewers from the suburbs is treated at either the Southerly

TABLE III.—1954 Flow Data for Cleveland Sewage Treatment Areas

Plant	1954 Flow			Cleveland Resident Population to Other Plants		Flow to Others (m.g.d.)
	Total (m.g.)	Total (m.g.d.)	Per Capita (g.p.d.)	Plant	Population	
Easterly	37,936.0	103.9	188.5	Euclid	668	0.125
Southerly:						
1954	17,137.6[1]	47.8[1]	117.4[1]	—	0	0
1955	21,754.0	59.6[2]	146.4[2]	—	0	0
Westerly	12,273.8	33.6	147.0	Lakewood	18,031	2.650
Lakewood	4,011.5	10.99	147.5	Cleveland[3]	10,341	1.525
Euclid[4]	—	—	—	Cleveland[3]	1,814	—
Cleveland Totals	67,347.4[1]	185.3	166.3	—	18,719	2.775

[1] Population correct as of 1954; flows not tributary for entire period 1954. See 1955 calculations for flow and strength in terms of B.O.D. and suspended solids for comparative purposes.

[2] 1955 Southerly flow data: 59.6 m.g.d., 143 p.p.m. B.O.D., and 224 p.p.m. suspended solids.

[3] To Cleveland from outside area.

[4] Hilltop District only.

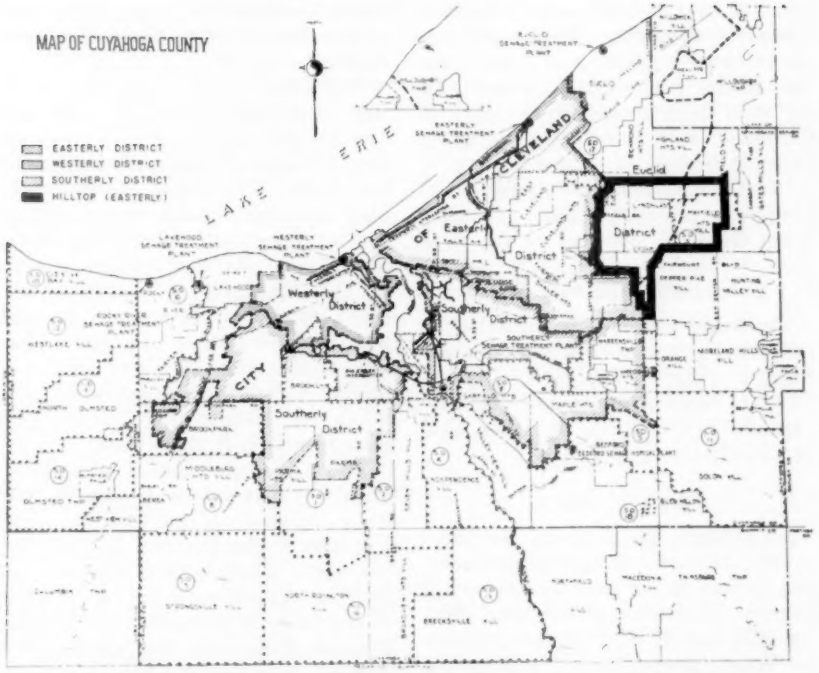

FIGURE 2.—Sewage treatment plants and sewer districts, Cleveland, Ohio.

or Easterly plant and is given 95 per cent treatment.

The sewage plants in Lakewood, Rocky River, and Euclid cannot provide more than primary treatment.

Population Served

As shown in Tables II, III and IV, a breakdown of population served indicates that, as of 1954, Cleveland-owned sewage plants served 79.2 per cent of the population in Cuyahoga County. Of the 1,187,000 persons tributary to the systems, 893,000 or 75.3 per cent were residents in Cleveland. The suburbs provided the balance (294,000 persons) or 24.7 per cent of the connected population.

The sewer areas served in Cuyahoga County by the City of Cleveland are shown in Figure 2.

TABLE IV.—Sewage Service Sales 1954

User	Cost[1]		Population Served (%)
	($)	(%)	
City of Cleveland	1,654,478.02	71.4	75.3
Suburbs:			
Direct service	456,126.97	19.7	24.7
Master meter	203,763.36	8.8	
Miscellaneous	6,119.82	—	—
Total	2,320,488.17	—	—

[1] No charge is made for use of Cleveland sewers or storm outlets in these rates.

Costs of Operation

The total costs of operation for 1954, prorated by flow to the plants

TABLE V.—Operation and Maintenance Costs, 1954

Plant	Flow (m.g.)	Costs ($)	
		Total	(per m.g.)
Easterly	37,936.0	802,835.67	21.16
Westerly	12,273.8	198,483.78	16.17
Southerly	17,137.6	221,534.41	12.93
Total	67,347.4	1,222,853.86	18.16

operated by the division, are shown in Table V. Including all overhead and administrative costs, total costs average $33.08 per million gallons. Of the total flow treated by the City of Cleveland, only 18 per cent was given primary treatment.

Plant capacity has been sufficient to treat all tributary flow, including storm flows, 97 per cent of the time.

Comparative Service Rates

The latest available information on water and sewage service rates in other cities is given in Table VI. These costs are based on an annual consumption of 15,000 cu. ft. of water used per family.

Financial Status

At present, the financial condition of the Division is not satisfactory. Net income is not sufficient to safely finance an operation of this size. During 1953 and 1954, if it had not been for income derived from bond money invested prior to certification for new construction (now completed), the division would have had insufficient cash to operate. It is now necessary to spend $2 million for additional filters and incinerators. This additional cost will increase the need for higher rates.

Rates have not been increased for the suburbs since 1941, a period of 15 years, and the Cleveland rates were raised from $0.18 to $0.25 in 1950. That rates must be raised is most obvious.

Plant Administration

It is with considerable pride that the City of Cleveland has accepted the task of supplying water and sewerage service for so much of Greater Cleveland.

The latest edition of the Division of Sewage Disposal's annual report was 1954. It was mailed to 20 states, 1 territory, and 3 foreign countries, and is valued as a working tool by many sanitary engineers. The major part of the data for this paper was taken from this report.

The secret to the successful operation of the plants is in no small part due to the engineers who have designed the plants and have anticipated the needs. The plants are well operated and maintained because qualified engineers direct the day-to-day operations. At the recent opening of the Southerly sewage treatment plant, 88 employees out of 190 (this includes the whole Division) had served the city 15 years or more. Twelve have served 25 years or more, which is indicative of the interest these men have in their work.

There is a grave handicap in being unable to pay adequate salaries and make needed adjustments in pay schedules. The Division is bound by the same schedule and receives the same consideration for salary increases as any other department in Cleveland, in spite of the fact that no money is derived from tax funds and it must manage to stay within its income and meet all expenses.

Cleveland Metropolitan Needs

Greater Cleveland has "suburbanitis." Villages suddenly discover they are cities, but are still thinking as villages in terms of services. The broad concept of the needs of the community includes such things as police and fire protection, schools, zoning, airports, roads, harbors, and many others. The latest study group to work on these problems, common to all communities, is the Cleveland Metropolitan Service Commission, headed by T. Keith Glennan, of Case Institute of Technology. This group will study the facets of services needed on a community basis. The Cleveland regional planning group has prepared a master set of sewer plans for virtually the entire county and has made recommendations.

The future needs of any community involve land usage. Cleveland itself

TABLE VI.—Gross Amounts for Water and Sewage Service *

Location	Water			Sewage		
	Minimum Rate ($)	Consumption Allowed (cu.ft.)	Annual Cost ($)	Minimum Rate ($)	Consumption Allowed (cu.ft.)	Annual Cost ($)
Cleveland, within territorial limits	1.50	1,000	14.45	0.25 0.25†	1,000 Flat rate	3.75
Cleveland, suburban, low and 1st high service	1.80	500	26.42	0.46†	Flat rate	6.90
Cleveland, suburban, 2nd high service	1.80	500	37.04	0.46†	Flat rate	6.90
Cleveland, suburban, 3rd high service	1.80	500	46.77	0.46†	Flat rate	6.90
Akron	4.40	1st 2,000	32.30	2.20	2,000	16.50
Akron, suburban	4.84	1st 2,000	35.53	2.42	2,000	18.15
Akron, repumpage	5.72	1st 2,000	41.99	2.86	2,000	21.45
Alliance	3.75	1,000	41.40	1.35+ 9% gross water bill		7.78
Alliance, suburban	4.13	1,000	42.92	3.60+24% gross water bill		20.74
Ashtabula	6.00	1,200	69.90	1.10—max. 1.85		7.35
Ashtabula, suburban	—	—	—	1.70—max. 2.80		11.10
Canton	2.72	2,000	18.00	70% gross water bill		12.60
Canton, suburban	3.00	2,000	19.70	100% gross water bill		19.70
Cincinnati	3.25	1st 2,000	23.50	1.60	1st 2,000	12.00
Cincinnati, suburban	6.50	1st 2,000	47.00	1.60	1st 2,000	12.00
Columbus	3.00	None	26.25	1.20	None	20.25
Columbus, suburban	4.50	None	33.75	2.40	None	33.75
Dayton	2.10	1st 1,000	24.90	1.50	1st 3,000	8.40
Dayton, suburban	2.63	1st 1,000	31.12	1.87	1st 3,000	10.50
Elyria	3.75	None	41.25			
Elyria, suburban	4.14	None	45.30	50% of water bill		22.65
Findlay	3.00	None	38.50	—	—	11.48
Findlay, suburban	3.30	None	42.35	—	—	17.22
Lima	3.00	1st 500	27.00	2.00	1st 500	12.40
Lima, suburban	3.30	1st 500	29.70	5.00	1st 500	31.00
Lorain	3.85	1st 2,000	27.30	1.70	1st 2,000	12.75
Mansfield	3.00	None	51.00	0.50	None	12.00
Mansfield, suburban	3.30	None	56.10	0.75	None	18.00
Massillon	6.30	1st 600	72.30	Flat rate		5.00
Massillon, suburban	—	—	—	Flat rate		5.50
Middletown	2.25	1st 1,000	25.50	3.00	1st 1,000	39.50
Middletown, suburban	3.00	1st 1,000	30.15	4.50	1st 1,000	59.25
Ravenna	3.60	1st 1,000	54.00	1.30	1,000	14.10
Springfield	3.00	None	45.00	0.50	None	7.20
Springfield, county	3.60	None	54.00	1.00	None	14.40
Toledo	2.60	2,000	19.50	1.40	None	12.90
Toledo, suburban	2.86	2,000	21.45	1.95	None	18.15
Youngstown	3.00	1st 1,000	41.70	Rate expected to be 100%		41.70
Youngstown, suburban	3.75	1st 1,000	52.18	Rate expected to be 100%		52.18

* Based on 15,000 cu.ft., $\frac{3}{4}$-in. meter.
† Per 1,000 cu.ft.

has seen no great surge of home construction, but its suburbs have. Industrial sites are valuable to the extent that rail facilities, power, roads, sewers, and water are provided. Sewers transform farm lands into urban communities. The lack of regional planning on this one issue is the unsolved problem in the Cleveland suburban area.

Septic tank systems are at best a makeshift arrangement. The question then becomes, "How best can the community sewer needs be served?" People tend to confuse sewers with sewage plants. People confuse the water treatment plants and the distribution system, which are owned by the communities in most cases. The supply does not fail, the distribution system fails. In terms of sewerage, the collection system of sewers is the bottleneck and the reason new streets are built with septic tanks when the problem should really be solved on a regional basis.

Present Statutory Authority

Under the County Sewer District Law, the county has limited power to put in needed sewer improvements because of lack of power and the need to deal with various incorporated areas individually in order to get agreement between the parties.

In 1949 the General Assembly passed enabling legislation (General Code, Section 6781, *et seq.*) providing a means of extending to any existing political subdivision the means of creating a Regional Water and Sewer District, which could act as a separate identity, governed by a Board of Trustees, to provide that area with proper water and sewer facilities. The district would have broad powers, and revenue bonds for as long as 45-year maturity dates could be issued. To date, no such authority has been set up in Ohio, so the credit rating of such an authority cannot be determined.

Regional Planning Commission

At the 1950 election the voters of Cuyahoga County approved the expenditure of $500,000 to prepare a comprehensive survey of the needs of water purification, filtration, and distribution for the county and metropolitan areas adjoining. The sewerage program was to be studied on the same basis.

In addition, the City of Cleveland along with the County Commissioners, contributed $10,000 each as an additional sum for the study of the regional aspects of the proposed unification. The Utilities Department has several members serving on various engineering committees coordinating the work of the Cleveland Regional Planning Commission.

Some of the benefits derived to date include the following:

1. The completion of base maps for a master sewer plan for almost all of Cuyahoga County.
2. The review of the master plan, with recommendations as to routes and future needs. (This is being studied by a consulting engineer.)
3. A mutually satisfactory project between Cleveland, Maple Heights, and Garfield Heights, which involved construction of retarding reservoirs in the Mill Creek valley to prevent flooding.
4. An immediate solution to the Euclid Hilltop area sewage problem in which a proposed county plant was eliminated by using Cleveland facilities.
5. Recommendations and steps to be taken by any political division wishing to take advantage of the enabling legislation.

Extension of Services

Hilltop Sewer District

The Cleveland Regional Planning Commission has sponsored a plan whereby the now overloaded and inadequate City of Euclid sewage plant

can be relieved of flow from parts of South Euclid, University Heights, Beachwood Village, and Mayfield Heights by diverting 4.5 m.g.d. of sewage into the Easterly sewage plant.

This area is known as the "Hilltop District." The use of land for residential purposes in this area has been hampered by lack of sewers. In fact, an injunction preventing further building in the east side of Mayfield Heights was in force up to the first of 1956, until a solution for sewage treatment was provided. This injunction created a backlog of $30 million of new home construction. The City of Cleveland agreed to provide immediate sewage service at the Easterly sewage plant for the area of approximately 11,000 acres which will have an ultimate population of 150,000 and, at 200 g.p.c.d., a maximum flow of 30 m.g.d. The flow for the year 2000 is estimated at 11.34 m.g.d. (at 312.5 g.p.c.d.). The rate for this service will be $0.46, which will be less than the $1.00 per 1,000 cu. ft. that the City of Euclid would have charged.

The City of Cleveland must make certain improvements at the Easterly plant, as this flow will enter the Collinwood sewer system and must be pumped at the plant. The rate will include the cost of necessary pumping and capital expenditures. In any event, the Cleveland Regional Planning Commission has cited that the saving is some $2 million over that of a new county plant for the area to be served by the City of Cleveland. The entire contract for sewers was bid at $1,022,279.

Rocky River Plant Expansion

Some interesting comments have appeared in the local papers as to the inability of the suburbs west of Rocky River to agree to the method of financing and enlarging the Rocky River sewage treatment plant. In this instance, the county financed the original plant and operates it. The plant is owned by Rocky River, Bay Village, and Fairview Park. The costs are assessed against the properties benefited, with the ownership to revert to the communities when the bonds have been paid. The county assesses the communities and deducts the amount due from the tax revenue, semi-annually. Enlargement is necessary and no agreement can be reached between the parties. A study of the sewer district map of the area involved indicates that either the Lakewood plant or the Southerly plant could be used to provide sewer service for this area, if so desired.

Without the benefit of an engineering survey, it is obvious that the southern part of Fairview and the surrounding communities need a sewage plant. However, the discharge of even the best sewage effluent possible into Rocky River would cause additional pollution in this scenic park. Lakewood, although at present overloaded and outmoded, has a discharge point in Lake Erie in an area not surrounded by beaches. The alternate would be to utilize the Southerly plant, which provides complete treatment and can be enlarged to 100-m.g.d. capacity. A survey is now in progress and the City of Cleveland has indicated that this area will be given the same consideration as the Hilltop project.

Cleveland's Participation in the Regional Program

It is felt that some of the features outlined in the Cleveland Regional Planning Commission report (1) should be seriously considered by those areas needing sewers and sewage facilities; that this authority be separate from any existing political identity, and operate much as has been suggested, and is being done by such authorities as the Chicago Sanitary District or the Minneapolis-St. Paul Sewer Commission; that problems of intercepting sewers and storm

reliefs be then delegated to this group; and that the power to tax the benefited property then be granted so the organization will be self-sustaining.

Cleveland has little need to delegate the operation of plants to others, for the department at present serves as a "common carrier," in terms of sewage treatment, for 79 per cent of Metropolitan Cleveland. The department has given good sewage service at lower rates than is obtainable elsewhere.

Therefore, it is recommended that a regional commission of sanitation, separate from any existing political subdivision, and mandatory under the enabling legislation, be established; that this group be charged with the planning, building, and financing of all new storm and intercepting sewers for Greater Cleveland or whatever area is at first joined in a common sewer district; that title be given to this group in terms of a 45-year lease to all existing sewers classified as storm or interceptors and that all debt and interest be assumed and payments made to compensate the present owners, with taxes levied against the benefited properties; that the board of trustees be composed of prominent men, qualified to represent those parties interested in comprising the group and that a chief engineer be hired as Administrative Officer; that any local sewer system belonging to any community can be taken into the system at any future date if so desired; that the board lease the necessary sewage disposal facilities; and that the Commission have the authority to administer, tax and enforce actions of the Authority.

City of Cleveland's Role

The City of Cleveland is willing to take over the operation of all sewage plants in Greater Cleveland. It will be willing to pay reproduction costs less depreciation based on a 25-year plant life to those owning separate facilities. It will be willing to take over the maintenance of all regulating devices, sewage diversions, operate and maintain all pumping stations. This will assure satisfactory operation of those sewers (including maintenance) belonging to or leased to the regional commission of sanitation.

In order that the City of Cleveland be compensated for services rendered, it will require that:

1. All sewer service charges be based on metered water consumption as billed by the Division of Fiscal Control.

2. A uniform contract rate be charged for all suburbs sufficient to pay for all costs of maintenance, operation, debt, interest, reserve depreciation, and overhead of Cleveland-owned facilities or those operated under the lease agreement. Furthermore, there shall be no special concessions and all prior agreements would be terminated.

3. The City of Cleveland be guaranteed the revenue equivalent to the metered water consumed and that the commission pay from funds derived from tax assessment any deficiency or delinquency.

Advantages of the Proposal

Among the advantages of the foregoing proposal are the following:

1. The functions of the present County Sanitary Engineer's office would serve as the engineering staff and would design and construct sewers in needy areas.

2. The operating division would be formed from the personnel now operating the Cleveland plants and any others taken into the system. The County Sanitary Engineer's sewer maintenance forces would continue to function as the sewer maintenance group, with increased responsibilities. A single administrative head would be in charge of maintenance and operations.

3. Any community entirely separate from the proposed reorganization by virtue of drainage area and facilities as existing, need not join in the venture, but may at any later date.

Summary

In order for any plan to succeed, the desire to solve the problems must be met with willingness to make concessions. The formation of a regional commission of sanitation to administer the division would grant this group broad powers. The need to have a check on such a group is within the organizational framework and should be worked out.

Leasing of facilities owned by the City of Cleveland, now operated by the Department of Public Utilities, seems to be the only way, financially, that the City of Cleveland could provide sewage service to suburban Cleveland. This proposal is made because of the absence of any responsible group to buy out the investment made by the City of Cleveland since 1899, which now stands at $45 million and which includes a $16,852,000 investment made from general funds for sewage treatment works prior to the creation of the Department of Public Utilities.

Expansion of the duties of the operating division to be responsible for proper sewer functioning should do much to relieve pollution of waterways traced to lack of proper maintenance.

To finance the construction of new works and to modernize existing devices, a sound method of financing is necessary. In general, it has been possible to finance the improvements at rates of interest between 1¾ and 2¾ per cent on the basis of past credit rating and the issuance of sewer revenue bonds.

A working agreement with the Division of Fiscal Control is absolutely necessary to bill accounts on the basis of water consumption. The present organizational arrangement makes this possible.

Reference

1. "The Sewer and Water Problem." Cleveland Regional Planning Commission, Cleveland, Ohio (1953).

COOPERATION INVITED

Early remittance of 1957 membership dues to the Member Association secretary will assure continued receipt of the Journal. The names of delinquent members are removed from the mailing list prior to the mailing of the February issue of SEWAGE AND INDUSTRIAL WASTES. Reinstatement is time consuming and costly to the Federation and its members. In addition, each extra handling of a member's record multiplies the chance for error.

Your cooperation in prompt payment of dues will insure efficient service. Refer to page 4a of this issue for the name and address of the secretary of your Member Association.

VOLATILE ACIDS BY DIRECT PHOSPHORIC ACID DISTILLATION *

JAMES E. FROOK

Chemist-Bacteriologist, Sewage Treatment Plant, Toledo, Ohio

Volatile acid analyses of digester sludges serve a useful purpose in the effective operation of digesters. However, most methods for determining volatile acids are time consuming and complicated. Even the empirical method described in the Ninth Edition of "Standard Methods for the Examination of Water and Sewage" (1) involves a direct distillation, using a dilute sulfuric acid solution, and is open to criticism since the hydrolysis of organic material may occur when the sample is not properly prepared. Buswell (2) recognized this and suggested the removal of sludge and suspended matter prior to distillation. At best, the volatile acid recoveries by this method are both low and variable, ranging from 65 to 85 per cent.

Heukelekian and Kaplovsky (3)(4) have developed a steam distillation method giving 92 to 98 per cent recovery of the volatile acids. A close adaptation of this technique appears as the recommended procedure in the Tenth Edition of "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes" (5), with the direct sulfuric acid method reduced to a tentative status.

Thomas *et al.* (6) reported an ether-extraction method of volatile acid analysis based on the solubility of the acids in ethyl ether, which removes the higher acids from solution prior to titration in the conventional manner. More than 95 per cent of the volatile acids is recovered.

While these newer methods have obviated the faults of the direct sulfuric acid distillation method, they are somewhat lengthy and require special equipment setups. In an effort to simplify the analysis, an investigation was made on a variation of the direct distillation method, using the conventional Kjeldahl apparatus.

Volatile Acids

The acids found in anaerobic digester environments are of the fatty acid series, which extend from formic acid to the long-chain insoluble high molecular weight acids. The acids having 1 to 10 carbon atoms in straight chains are indicated in Table I.

This series continues; however, those acids with more than 10 carbon atoms in a straight chain are virtually water-insoluble solids under normal conditions. Also, it is doubtful that any acids other than acetic, propionic, n-butyric, and possibly n-valeric will be found in solution in digesting sludge.

Method

The project as originally planned was to develop a variation of the direct distillation method, making the test as simple as possible, yet reliable, and with a high degree of volatile acids recovery. An electrically heated 550-w. Kjeldahl distillation apparatus was the principal unit used. Small amounts of 85-per cent phosphoric acid were substituted for the sulfuric acid specified in the conventional acid distillation method. It was quickly discovered that the volatile acid distillation rate was too low. Therefore, the amount of phosphoric acid was increased to 50 ml., and the total volume

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TABLE I.—Fatty Acids Series with 1 to 10 Carbon Atoms

Name	Formula	Molecular Weight	Solubility (g./100 parts of H_2O)
Formic	HCOOH	46.03	Infinite
Acetic	CH_3COOH	60.05	Infinite
Propionic	CH_3CH_2COOH	74.08	Infinite
N-butyric	$CH_3(CH_2)_2COOH$	88.10	Infinite
N-valeric	$CH_3(CH_2)_3COOH$	102.13	3.7
N-caproic	$CH_3(CH_2)_4COOH$	116.16	0.4
N-caprylic	$CH_3(CH_2)_6COOH$	144.21	0.25
N-pelargonic	$CH_3(CH_2)_7COOH$	158.24	Very slight
N-capric	$CH_3(CH_2)_8COOH$	172.26	Very slight

of the sample, including the sludge sample, was increased to 200 ml. The phosphoric acid lost its water in the distillation process so that actually nearly 158 ml. of distillate were collected.

To judge the deficiencies of the method, the distillation rates were closely observed. Twenty-five-milliliter increments of the distillate were collected and titrated at once with 0.1 N NaOH. In this way, a deviation from expected rates could be detected early in the process.

As previously mentioned, the presence of suspended material could produce hydrolysis. Accordingly, proper sample preparation was necessary. Simple filtration was not sufficient, as colloidal material passed through the finest filter paper. Aluminum sulfate and ferric chloride were used to develop a gelatinous floc, and a clear filtrate was produced under these conditions. However, the excess ferric chloride broke down later in the distillation process and hydrochloric acid appeared in the distillate. The use of aluminum sulfate and lime to produce a floc under slightly alkaline conditions proved successful. The gelatinous floc formed was allowed to coat the surface of a qualitative filter paper (E. & D. 615) and the collected filtrate was refiltered until clear. In the digesting sludge the colloidal matter was not particularly evident and filtration was quite easy. With sludges high in acids and low in pH there was some difficulty in removing the solid and colloidal matter, but even under these conditions sufficient sample was readily obtained.

The distillation rates still indicated excess acid late in the distillation process. Since chlorides were a proven source of interference (NaCl and NH_4Cl decompose), a saturated solution of $AgSO_4$ in distilled water was used satisfactorily to precipitate and hold back the chlorides.

Blanks run on the phosphoric acid-silver sulfate mix usually required about 0.4 ml. of 0.1 N NaOH, depending on the volatile acids present in the phosphoric acid. These acids apparently were principally acetic, to judge from the distillation rate.

Distillation of the pure volatile acids under test conditions was made to determine the amount of recovery possible (Table II).

Aqueous solutions, 0.5 per cent by volume, were used in all the distillation tests except for n-caproic and n-caprylic acids, where lesser strengths were used, due to decreasing solubility. Aliquots of the diluted acids were distilled in varying concentrations up to 5,000 p.p.m. when possible. The distillation rate curves for the various standard acids are shown in Figure 1. Distillation rates were not dependent on the concentration of the acids. The n-caprylic acid solidified in the cold condenser and required manipulation with a hot condenser to wash down and dissolve the acid; all other acids distilled satisfactorily. Visual observations of the distillate indicated that n-caprylic acid is probably not present in solution in digester sludge. Steaming out of the condenser after some 40 distillations of digester sludge indicated only traces of solidified acids.

TABLE II.—Per Cent of Acid Recovered

Acid	Recovery (%)
Acetic	98.2
Propionic	98.8
N-butyric	98.9
N-valeric	97.4
N-caproic	97.8
N-caprylic	93.8

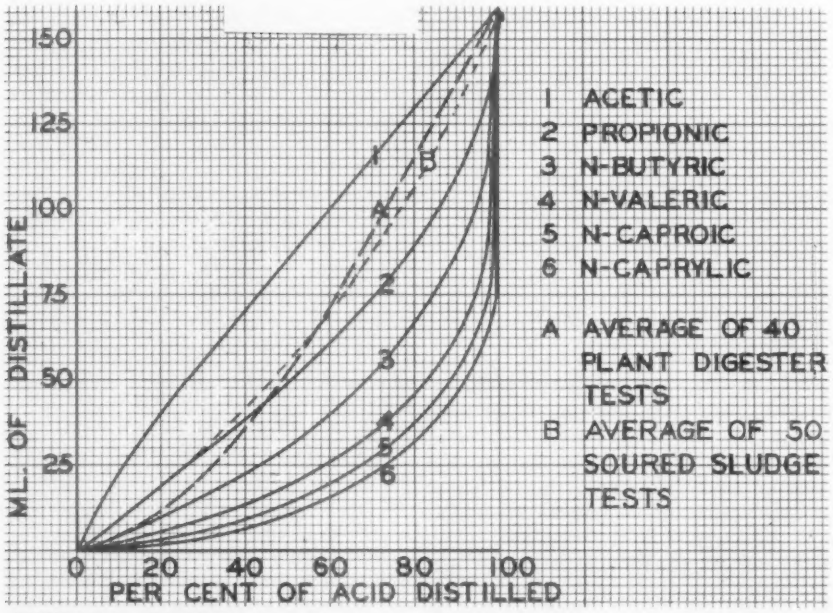

FIGURE 1.—Distillation rate curves for various standard acids; well-digested sludge, curve "A"; and soured sludge, curve "B."

Application

Much of the previously mentioned work was done in the summer of 1955, during the first half of a two-month period when the Toledo sewage treatment plant was being by-passed. Sludge was not fed to the seven operating digesters during this period, consequently, there was ample time to produce highly digested sludges. Some tests were made on the digesters before the feeding of raw sludge was resumed, after feeding began, during the acid phase, and finally when conditions were regarded as normal. Data were collected on the pH, volatile acids and volatile dry solids (in solution) of the digester sludge, and the carbon dioxide content of the digester gas (Figure 2).

Averages of the digester tests were made daily. Since the plant gas was a composite of all digesters, individual digester gas analyses were not made.

There was good correlation of the volatile acid concentrations with the digester pH and with the carbon dioxide content of the gas, and to a lesser extent, with the volatile dry solids in solution. Using the volatile acid test as a guide, the feeding of raw sludge to one of the digesters was halted when the acid concentration reached 620 p.p.m. and the pH had dropped to 5.8. Recovery to 48 p.p.m. acids was accomplished with a three-week rest period, and sludge feeding was resumed without further trouble.

The average of a number of distillation rates produced the representative curve "A" (Figure 1). It is significant that this curve is within the acetic-butyric acids range, and follows somewhat closely the distillation rate for propionic acid. This agrees with the observation of Heukelekian and Kaplovsky (3) that the molecular weights of the digester acids are approximately that of propionic acid. It therefore is likely that volatile acid calculations should be made on the basis of propionic acid. How-

ever, for the purposes of this paper, all calculations are made on the basis of volatile acids as acetic acid.

There was doubt as to whether or not the distillation rates might exceed the apparent limits for acetic-butyric acids. Where the 0.1 N NaOH titration amounted to less than 1 ml. for a 150-ml. sample, the rates of distillation could not be closely determined. However, no distillation which required more than 1 ml. of NaOH in the titration exceeded the acetic-butyric acids distillation limits at any point.

Sour Sludges

To test this observation further, digester sludge studies were made in the laboratory. The over-feeding of raw sludge to a digester reduced the pH to 5.05 and raised the volatile acid content to 5,700 p.p.m. Of more than 50 distillations, not one exceeded the acetic-butyric acids limits, nor were there any significant variations from the distillation rates of well-digesting sludge. The method, therefore, also can be applied to sour sludges. Curve "B," Figure 1, represents the average acid determination for the sour sludges.

Limitations

The limitations of the method were tested. Chlorides interfered with the test and had to be retained in the Kjeldahl flask. There was no difficulty experienced with bicarbonate alkalinity, heating rates, silver sulfate breakdown, ammonium compounds, or the breakdown of the organic acids. There is no effect on the distillation from the flocculents, aluminum sulfate, and lime. The flocculents form calcium salts of the acids which decompose readily in the phosphoric acid distillation.

The method failed when applied to fresh pumpkin cannery waste. Sugars and starches will decompose during

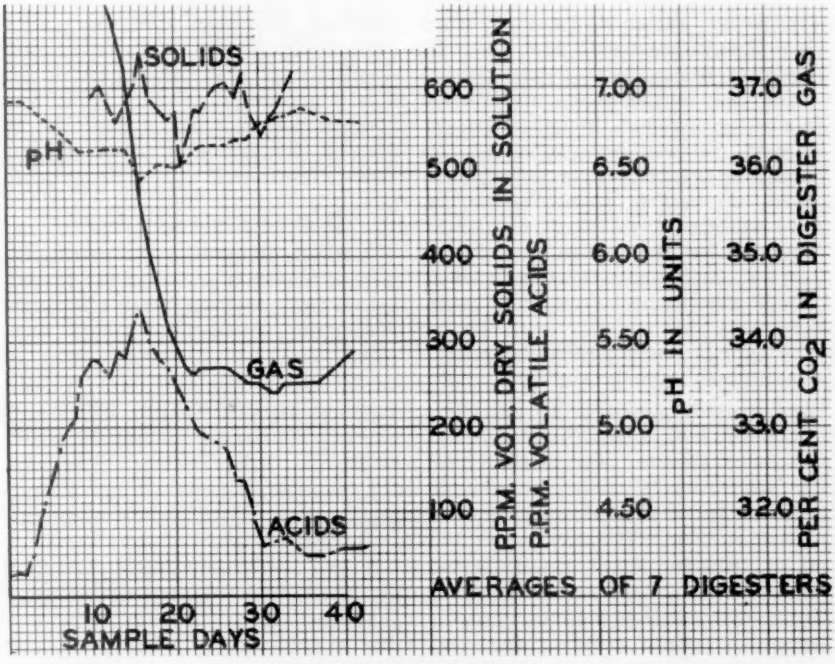

FIGURE 2.—Digester data.

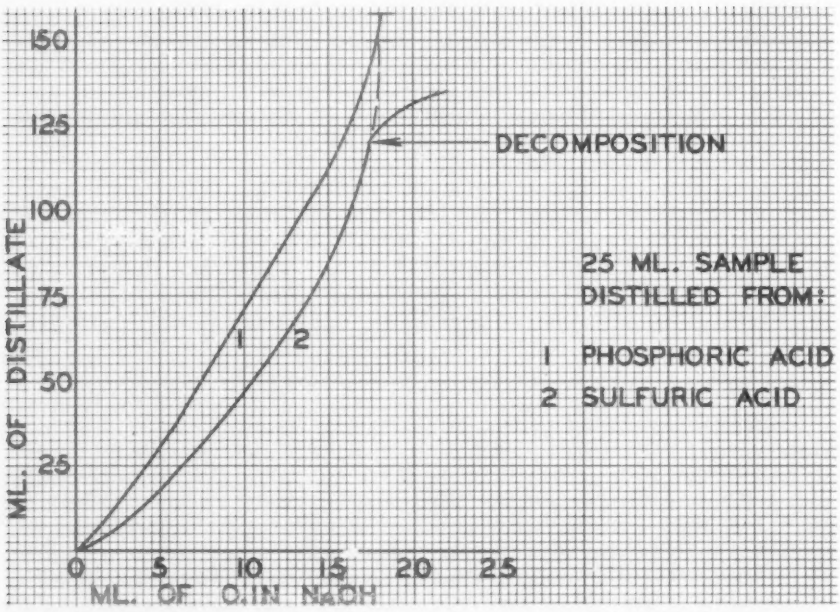

FIGURE 3.—Comparison of phosphoric acid and sulfuric acid distillation curves.

distillation, but it is not likely that these compounds would be present in digesting sludges.

The best technique was distillation to acid dryness and the quick removal of heat, followed by purging of the condenser system, using a separate source of heated water; preferably from another Kjeldahl flask. Dropwise addition of water as a condenser purge to the hot phosphoric acid when at acid dryness apparently will cause hydrolysis.

In an interesting side investigation, concentrated sulfuric acid was substituted in equal quantity for the phosphoric acid and distillations were made using clear filtrate. The elevated boiling temperatures made the volatile acid distillation rate higher than with phosphoric acid. However, when 120 ml. of distillate out of a possible 150 ml. had been collected hydrolysis was detected. A charring of the material remaining in the Kjeldahl flask was quite evident by the time 130 ml. of distillate had been collected. However, nearly all the volatile acids were distilled over with the 120 ml. of distillate, and results at that point were checked within 2 per cent of the results of the phosphoric acid distillation (Figure 3).

Summary and Conclusions

A direct phosphoric acid distillation method has been presented for investigation and appraisal, using a Kjeldahl distillation apparatus, simple technique, and with recovery rates of better than 98 per cent on all volatile acids to be expected in solution in digester sludges. Conclusions drawn are:

1. Sample preparation for a clear filtrate is essential, but is easily accomplished.

2. The entire test requires about 2 hr. to complete, including filtration and distillation.

3. Acid recoveries of 98 per cent of the acetic, propionic, n-butyric, n-

valeric and n-caproic acids are possible. The n-caprylic acid may be recovered by using a hot condenser.

4. Acid distillation rates suggest that calculations should be made on the basis of propionic acid, rather than acetic acid.

5. The composition of the mixed acids changes slightly, when partially-digested sludges are compared with well-digested sludges.

6. The distillation curves suggest that the mixed acids consist principally of acetic, propionic and n-butyric acids.

7. Phosphoric acid does not decompose the solids in solution. As little as 4 p.p.m. volatile acids were recovered from a solution containing 600 p.p.m. volatile dry solids in solution.

8. There is no hydrolysis of the sample.

APPENDIX—DIRECT DISTILLATION OF VOLATILE ACIDS WITH PHOSPHORIC ACID

1. The amount of sample desired is dependent on the volatile acid content. However, 150 ml. of clear filtrate is sufficient for low acid sludges, and 25 ml. is ample for sour sludges.

2. Remove as much of the solids as possible from the sample by settling and decanting, if necessary. To the decanted liquor add about 0.1 g. of powdered aluminum sulfate and dissolve. Using a pH meter, add powdered lime to raise the pH to about 7.5. Stir the flocculated sludge and pour into a filter using a fast paper (for example, E. & D. #615). Allow the mixture to coat the filter paper surface. Pour the filtrate back through the filter until it runs clear and then collect the sample.

3. Into a 500- or 650-ml. Kjeldahl flask place 50 ml. of 85 per cent phosphoric acid, 5 ml. of saturated $AgSO_4$ solution and 150 ml. of clear filtrate, or filtrate plus water to make 150 ml.

4. Distill 162 ml. into a graduated cylinder or distill until acid dryness is indicated by the spattering of the drops of refluxing water. Remove heat from the Kjeldahl flask and allow to cool partly; then replace with a hot Kjeldahl flask for a purge of the condenser system. Purge 5 to 10 ml. of water through the system and remove the graduated cylinder from the condenser. Empty the condensate into a 500-ml. Erlenmeyer flask.

5. Add five drops of phenolphthalein indicator solution to the total condensate, heat to near boiling and titrate with 0.1 normal NaOH.

6. Calculations:

$$\text{Volatile acids (as p.p.m. acetic acid)} = \frac{[\text{ml. 0.1 N NaOH (sample titration)} - \text{ml. 0.1 N NaOH (blank)}] \times 6{,}000}{\text{ml. sample taken for distillation}}$$

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THREE TRACER METHODS FOR DETERMINING DETENTION TIMES IN PRIMARY CLARIFIERS

By Homer Ambrose, Jr., E. Robert Baumann, and Eric B. Fowler

Respectively, Graduate Student in Civil Engineering, Associate Professor of Civil (Sanitary) Engineering, and Associate Professor of Sanitary Bacteriology, Engineering Experiment Station and The Industrial Science Research Institute, Iowa State College, Ames, Iowa

Recently, a long-term study was undertaken at the Ames-Iowa State College sewage treatment plant at Ames, Iowa to determine the factors influencing the efficiency of each treatment unit. At present, a study of preaeration in sewage treatment is being conducted at the treatment plant. An understanding of the flow characteristics in the primary clarifiers is essential for conducting the preaeration studies. To evaluate these flow characteristics, a simple, accurate, and economical procedure had to be developed. To determine the detention time in the primary clarifiers, a full-scale plant evaluation was made of the most common experimental procedures. The two most common methods for determining detention time use salt and fluorescein dye as tracers. A third relatively new method uses a radioisotope as a tracer. All three methods have been utilized in the past by investigators interested in determining detention times in settling basins.

Previous Applications

The use of salt and dyes is no longer considered to be a sufficiently accurate method of determining detention times. However, tests during the past five years indicate that the radiotracer approach to determining detention time and for studying the flow of fluids may yield more reliable results.

In 1951, Thomas and Archibald (1) reported on tests for measuring longitudinal mixing in tanks with radioactive tracers. In 1953, Truesdale (2) reported on the measurement of detention time in four semi-scale settling tanks, each of 315-gal. capacity. Truesdale used salt, fluorescein dye, and rubidium^{86} as tracers, and reported good results with the rubidium^{86}. In 1953, Seaman (3) used potassium^{42} radiotracer to determine the detention time in a large lagoon-type settling basin. Seaman discussed the reported applications of radioisotopes in the study of flow patterns.

Ames, Iowa, Sewage Treatment Plant

The Ames-Iowa State College sewage treatment plant is of the trickling filter type, treating all domestic sewage from the City of Ames and from Iowa State College, which have a total estimated population of 27,000. Figure 1 shows the layout of the sewage treatment plant. The plant is designed to treat an average sewage flow of 3 and a maximum of 5.55 m.g.d. The average flow through the plant for the years 1951, 1952, 1953, and 1954 was slightly less than 2 m.g.d. A detailed description of the plant has been published elsewhere (4).

Each of the four identical primary clarifiers has a working volume of 56,130 gal. They are 59 ft. long, 20 ft. wide, and vary in depth from 8.75 ft. at the inlet to 7.75 ft. at the outlet. A concrete baffle, 2 ft. from the inlet in each clarifier, is provided to reduce velocity and distribute the flow. Mechanical scrapers in each clarifier move the settled sludge into sludge sumps

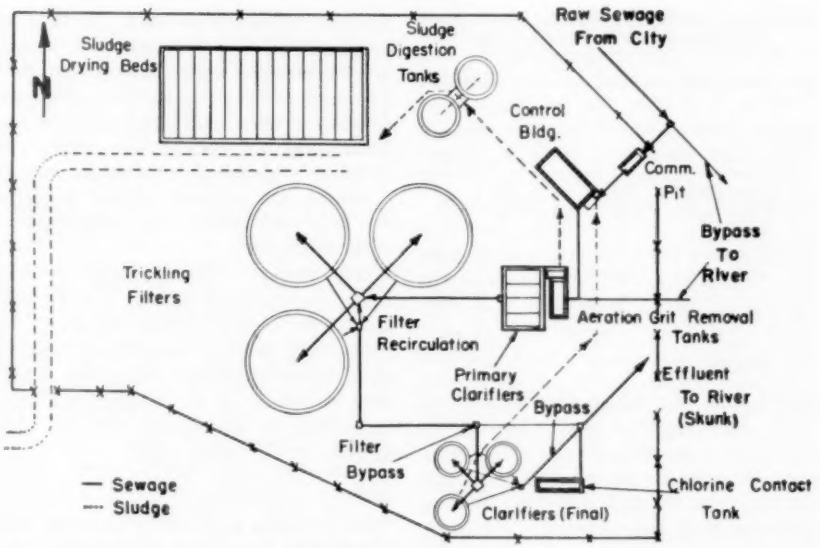

FIGURE 1.—Layout and flow diagram of the Ames, Iowa, sewage treatment plant.

located directly beneath the inlet ports.

During October 1955, a level survey was made on the primary clarifiers and weirs. Little settlement or differential settlement of the structure since it was constructed in 1949 was observed. Results of the survey indicated that the outlet weirs were relatively level and were not affecting the flow in a manner that would induce unequal flows through the clarifiers. However, a problem of unequal flow did exist, and special weir tests indicated that, for a given quantity of sewage entering the primary clarifiers, the flow was distributed in such a manner that the outside clarifiers receive one-and-one-half to two times the flow of the two inside clarifiers.

Experimental Procedures

In order to determine which of the three tracers previously mentioned was most practical for use in full-scale plant tests, all three tracers were used in preliminary tests with each clarifier. The mean detention times determined through the use of each tracer could then be compared. By evaluating the test results, the most practical tracer technique could be selected.

Initially, several tests were proposed in which all three tracers were to be used together in each clarifier. The concentration of each tracer would then be determined by separate analysis of each effluent sample for each tracer. This procedure would insure identical conditions of flow for each tracer in any one clarifier. Preliminary tests revealed, however, that when rock salt and fluorescein dye were introduced simultaneously into a clarifier, the fluorescein dye would interfere with the titration of the chlorides. Also, tests by Truesdale indicated that when salt and rubidium[86] were used together, the rubidium would remain with the salt. For these reasons, the three tracers were used separately.

Consequently, a testing program was scheduled whereby the mean detention time in each clarifier would be determined by using each tracer separately. Also, since it is generally be-

TABLE I.—Testing Schedule for Determining the Mean Detention Times in the Primary Clarifiers

Test (No.)	Tracer	Clarifier			
		1	2	3	4
1	Salt (lb.)	50	50	50	50
2	Dye (g.)	400	400	400	400
3	Salt (lb.)	40	—	—	—
	Dye (g.)	—	—	—	300
4	Salt (lb.)	60	—	—	—
	Dye (g.)	—	—	—	500
5	Rb^{86} (mc.*)	1	1	1	1

* Millicurie.

lieved that increasing the amount of tracer in a clarifier results in lengthening the mean detention time, identical tests were conducted in which only the amounts of rock salt and fluorescein dye used were varied. The program was expanded to include the determination of the mean detention time using varied amounts of rock salt in one clarifier and varied amounts of fluorescein dye in another clarifier. Table I shows the testing schedule.

A constant flow of 2.6 m.g.d. of sewage was pumped from the control house to the primary clarifiers for the duration of each test. With this constant flow it was next necessary to determine whether or not a uniform flow existed to each clarifier. The rates of flow leaving the clarifiers were determined, using four steel Cipolletti-type weirs in the effluent channel. Table II gives normal rates of flow.

TABLE II.—Normal Primary Clarified Flows

Clarifier (No.)	Flow (m.g.d.)
1	0.75
2	0.55
3	0.45
4	0.85
Total	2.60

Dosing and Sampling

One-half the amount of tracer to be used in a clarifier was introduced at each inlet port. Rock salt and fluorescein dye tracers were mixed in 20-gal. garbage cans containing 15 gal. of water at 80° C. Hot water was used to increase the solubility of the rock salt and fluorescein tracers. The radiotracers were mixed in 3-gal. buckets containing 2.5 gal. of tap water. A clarifier was dosed by simultaneously dumping the contents of two containers into the clarifier, one container at each inlet port.

All sewage effluent samples were taken manually in 305-ml. B.O.D. bottles at the outlet of each clarifier. In every test, several samples of effluent were taken prior to dosing the clarifiers to determine the background concentration in the sewage for the particular tracer being used.

Salt

In the first test, 50 lb. of rock salt in solution were used as the tracer in each of the four primary clarifiers. All four clarifiers were dosed simultaneously at the inlet ports, and samples of the effluent from each clarifier were collected at regular intervals. The Mohr method (5) was used for the chloride analysis of the effluent samples.

Fluorescein Dye

In the second test, 400 g. of fluorescein dye in solution were used as the tracer in each of the four primary clarifiers. All four clarifiers were dosed simultaneously, and samples of the effluent from each clarifier were collected at regular intervals. The concentration of fluorescein dye in the effluent samples was determined colorimetrically, using a Bausch & Lomb Spectronic 20 Colorimeter. Laboratory analysis of the fluorescein samples using a colorimeter was by far the simplest technique when compared with the analysis for chlorides or rubidium^{86}.

Variations

Two tests were made in clarifier No. 1 with varied amounts of rock salt and in clarifier No. 4 with varied amounts

of fluorescein dye. These tests were made to determine if greater amounts of tracer in a clarifier would produce longer mean detention times under the same conditions of flow.

Use of Rubidium^{86}

Rubidium^{86}, the isotope selected for use in this study, has a half-life of 19.5 days and decays to yield one beta ray of 1.822 mev. energy (80 per cent), another beta ray of 0.716 mev. energy (20 per cent), and one gamma ray of 1.08 mev. energy. This isotope is a relatively strong beta emitter, and has a half-life sufficiently short to preclude any lasting contamination which might occur above the safe limits. Calculations indicated that the radioactivity of the rubidium when diluted with the sewage would not exceed the safe limits for personnel handling samples and making laboratory analyses. Furthermore, Truesdale (2) pointed out in his preliminary tests on semi-scale humus settling tanks that less than 0.1 per cent of the rubidium was removed from the effluent by absorption on the humus settling in the tanks.

Isotope Procurement

Results from the tests using fluorescein dye indicated that 500 g. of fluorescein dye introduced into primary clarifier No. 4 produced a peak dye concentration of 3.5 p.p.m. On the basis of the results with the fluorescein tests, the total radioactivity required to produce a peak of 3,000 counts per minute from 200 ml. of sewage effluent was calculated to be 0.964 mc. With this calculation as a guide, 1 mc. of rubidium^{86} was used in each clarifier.

Rubidium^{86} was purchased from the Oak Ridge National Laboratory for use in the tests.

Counting

The technique for counting the radiation emissions consisted of measuring a specific volume of each sample into evaporating pans, evaporating the liquid so that only the solids remained, folding the pans to fit around a Geiger-Mueller counter, and counting the radiation emissions from each pan.

From each sample 200 ml. of sewage were measured and poured into an evaporating pan made of extra-heavy aluminum foil. The aluminum pans were 6 in. long and 2.5 in. wide with sides 1.5 in. high. They were sufficiently strong to contain 200 ml. of fluid without spilling during handling. There was no deformation of the pan due to the weight of the fluid. Two coats of Krylon were sprayed on the pans to prevent corrosion by chlorides in the sewage during evaporation. The pans were so designed that, when all the moisture had been evaporated, the pans could be unfolded and refolded to form a flat rectangular sheet 3 in. by 2.5 in. One side of the sheet had only one thickness of foil that would come in contact with all of the residue from evaporation in the bottom of the pan. With this design, only one thickness of foil separated the counter from the residue. The evaporating pans were placed in large autoclaves for about 48 hr. until all moisture had been driven off. The autoclaves were set for rapid drying under vacuum. The pans were then removed from the autoclaves and folded to fit the tube-shaped counter.

Geiger-Mueller counters were used for counting radiation emissions from the samples. The counters were 6 in. long, 2.36 in. in circumference, and had a cathode 3 in. long. Thus, a pan with dimensions of 3 in. by 2.5 in. could be folded around a counter with slight overlap and would fit the length of the cathode in the counter. Counts were registered on a standard scaler.

Standard Deviation and Background

For samples producing a high count (6), the standard deviation can be

computed by taking the square root of the number of counts. All samples taken during the early and critical period of the test were counted until at least 400 counts more than background count were registered on the scaler. Accordingly, the standard deviation for 400 counts would be about 20 counts. This procedure provided a standard deviation of not more than five per cent. For weak samples, the background rate contributes appreciably to statistical error. Therefore, the maximum standard deviation allowed in counting samples in the trail-off section of the curves was 10 per cent.

The background count was effectively minimized by shielding the counter with lead bricks before any counts were recorded. During the entire counting period the background count remained appreciably constant at 35 counts per minute, occasionally dropping to 32 or rising to 40 counts per minute. The total time for counting 140 samples was 18 hr. All counts were corrected for the decay rate of rubidium[86].

The field and laboratory techniques for protecting personnel while handling the rubidium were effective. Contamination was not found on the clothing or bodies of any personnel taking part in the test. The radioactivity of the final effluent discharged to the river 48 hr. after the test was less than 1 per cent of the safe physiological limits for drinking water.

Results

The purpose of using three different tracers in each clarifier for determining the mean detention time was to provide a sound basis for comparing the tracers when used under similar flow conditions. The tests provided full-scale experimental results.

In comparing the results using the three tracers, several important considerations must be kept in mind. First, the mean detention time in a primary clarifier should be less than the theoretical detention time for any given condition of flow. Therefore, a tracer which yields a mean detention time less than the theoretical detention time will be considered more favorably than a tracer which does not. Secondly, the same conditions of flow must exist in a clarifier each time a tracer is used if a reasonable comparison is to be made. Thirdly, a low flow may be expected to decrease the accuracy of test results using rock salt and fluorescein dye. This is due to fluctuations of the chloride content in the sewage, short-circuiting, density currents, and adsorption of fluorescein dye by the sewage. Finally, a radiotracer should not be affected by the rate of flow in the clarifier. The minute amounts of rubidium[86] which were used should not change the flow characteristics in the clarifiers, nor should a significant quantity of rubidium be adsorbed by the sewage.

Although the pumping rate from the control house was set at 2.6 m.g.d. for each test, there was a slight deviation from the normal flow in each clarifier at that pumping rate. However, this variation was not more than 0.05 m.g.d. in any clarifier. This deviation may have been caused by fluctuations in the rate of pumping at the time measurements were taken on the weirs in the effluent channel. Also, changes in the entrance conditions to the primary clarifiers caused by the sedimentation of solids in the influent channel and wind action may have affected the flow in the tanks.

The concentrations of chloride and dye and the counts per minute in the effluent samples were plotted against time of sampling to produce the curves from which mean detention times were determined. The curves for the rock salt and fluorescein dye tests were smoothed out. A three-point moving average in the recession and trail-off sections was used to produce a more regular curve. This method of plot-

TABLE III.—Mean Detention Times Determined with Three Different Tracers

Clarifier (No.)	Detention Time (min.)			
	Theoretical	Mean		
		Salt	Dye	Rb^{86}
1	108	110	76	69
2	147	156	121	73
3	180	194	130	120
4	95	136	77	79

ting was used to facilitate the comparison of the various characteristics of the tracers. The radiotracer curves show the actual counts per minute recorded. No attempt was made to use a moving average to define the curves.

Mean Detention Times

Figures 2 and 3 show the tracer concentration curves for the three different tracers used in the primary clarifiers. The mean detention time as determined with rock salt was always longer than the theoretical detention time (Table III). Conversely, the mean detention times determined with fluorescein dye and rubidium[86] were always shorter than the theoretical detention time.

Table IV shows the ratio of mean detention time to theoretical detention time for each tracer in the four primary clarifiers. This ratio has been called both the "efficiency rating" and the "flowing-through capacity."

In three of the salt tests, the mean detention time exceeded the theoretical detention time by less than 8 per cent. In the salt tests in clarifier No. 4, the mean detention time exceeded the theoretical detention time by 43 per cent. Thus, there is an indication that rock salt yields mean detention times which slightly exceed the theoretical detention times in the clarifiers tested.

TABLE IV.—Mean Detention Time Expressed as Per Cent of Theoretical Detention Time

Clarifier (No.)	Tracer (%)		
	Salt	Dye	Rb^{86}
1	102	70	64
2	106	82	50
3	108	72	67
4	143	81	83

The four fluorescein dye tests yielded mean detention times ranging from 70 to 82 per cent of the respective theoretical detention times. These mean detention times, all less than theoretical, approximated the anticipated mean detention times in the clarifiers.

The four radiotracer tests yielded mean detention times ranging from 50 to 83 per cent of the respective theoretical detention times. These detention times, all less than theoretical, were more varied than was anticipated when compared with the theoretical detention times.

From Table IV, it appears that fluorescein dye yielded the most consistent efficiency ratings. These efficiency ratings appear to have reasonably approximated the actual conditions in the clarifiers.

Effect of Variations in Tracer Quantities

Figure 3 shows the curves used in determining the mean detention time in clarifiers Nos. 1 and 4 using various amounts of rock salt and fluorescein dye, respectively. All of the mean detention times determined with the salt were longer than the theoretical detention time in clarifier No. 1. Conversely, all of the mean detention times determined with fluorescein dye were shorter than the theoretical detention time in clarifier No. 4. Table V shows the mean detention times and efficiency ratings determined with varied amounts of rock salt in primary clarifier No. 1.

The 50-lb. test yielded the shortest mean detention time, while the 60-lb. test yielded the longest mean deten-

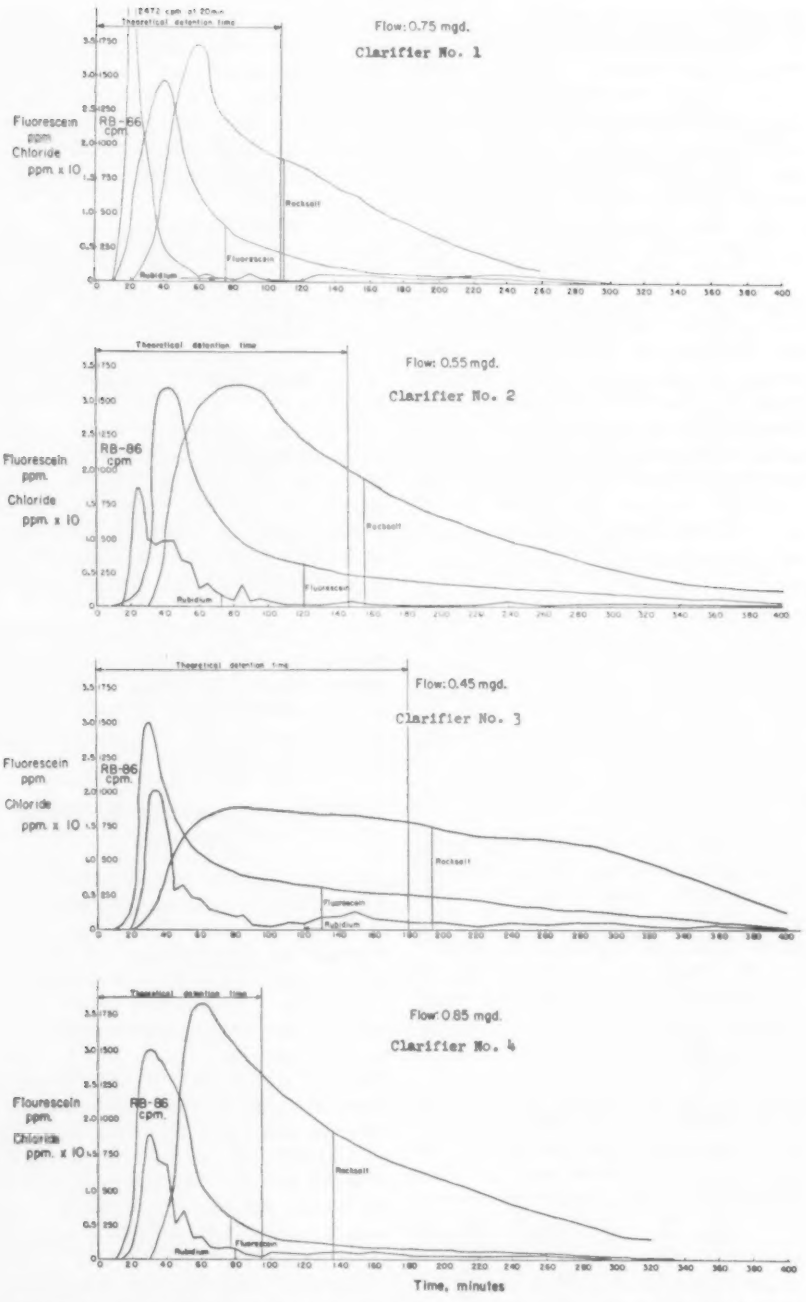

FIGURE 2.—Mean detention time curves using salt, fluorescein dye and rubidium[86].

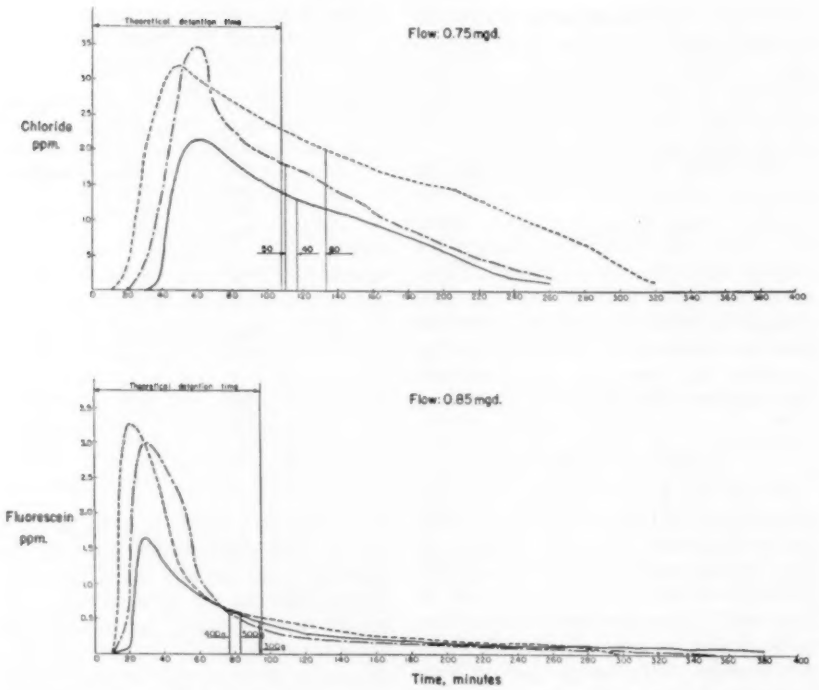

FIGURE 3.—Mean detention time curves using various amounts of rock salt and fluorescein dye.

tion time. However, this is an inconclusive indication that the mean detention time is lengthened by increasing the amount of rock salt used as a tracer.

Considerable difficulty was experieced in running two salt tests, due to fluctuating chloride content in the raw sewage. For example, at the beginning of one test, the normal chloride content in the sewage was about 50 p.p.m. when the rock salt was introduced. During the first 100 min., the test followed the usual pattern for salt with a peak of 32 p.p.m. above normal in 50 min. The chloride content then fluctuated, and during the next 100 min. rose to 122 p.p.m. above normal. Approximately 600 lb. of salt

TABLE V.—Mean Detention Times and Efficiency Ratings for Varied Amounts of Rock Salt in Primary Clarifier No. 1

Item	Rock Salt (lb.)		
	40	50	60
Theoretical detention time (min.)	108	108	108
Mean detention time (min.)	117	110	133
Efficiency rating (%)	108	102	123

TABLE VI.—Mean Detention Times and Efficiency Ratings for Varied Amounts of Fluorescein Dye in Primary Clarifier No. 4

Item	Fluorescein Dye (g.)		
	300	400	500
Theoretical detention time (min.)	95	95	95
Mean detention time (min.)	94	77	83
Efficiency rating (%)	99	81	87

would have had to be dumped into the sewage to produce such a large fluctuation. Later investigation revealed that a large-capacity ion exchange water softener had been regenerated at about the time the test began.

The 400-g. fluorescein dye test in primary clarifier No. 4 yielded the shortest mean detention time (Table VI), while the 300-g. test yielded the longest mean detention time. From these three tests there is no conclusive indication that the mean detention time in a clarifier is lengthened by increasing the amounts of fluorescein dye used as a tracer.

Recovery of Tracers

One of the factors which affects the accuracy of a tracer technique is the ability to recover a large portion of the tracer used. Previous investigators have indicated that the use of fluorescein dye was unsatisfactory because of the low recovery possible from raw sewage. The use of salt has been condemned because much of the salt remained in the bottom of the clarifiers as a result of density currents. This resulted in poor salt recovery and poor flow distribution. The per cent recovery of fluorescein dye was greater than the recovery of rock salt (Table VII). In six tests with fluorescein dye, the average dye recovery was 74.3 per cent. In the six tests with rock salt, the average salt recovery was only 51.9 per cent. Fluorescein dye recovery was the most consistent, varying between 74 and 80.5 per cent in five of the six tests.

Primary clarifier No. 4 had the greatest rate of flow, which resulted in a high recovery of both salt and dye. This rapid flow may have reduced the detention time sufficiently to curtail the formation of chloride density currents and also may have reduced the time in which the sewage could adsorb the fluorescein dye.

Recovery of the radiotracer, rubidium[86], was not determined for several reasons. First, a counting procedure was used which provided for counting most but not all of the radioactive material in each sample. All counts were relative as long as the same counting procedure was followed. Secondly, there is no way of knowing what per cent of the total emissions from the rubidium actually caused the counter to register. Maintaining the same counting procedure for every sample could result only in a relative comparison of the amount of rubidium in each sample, not the actual amount of rubidium.

TABLE VII.—Per Cent Recovery of Rock Salt and Fluorescein Dye

Clarifier (No.)	Tracer		Recovery (%)
	Type	Quantity	
1	Salt	40 lb.	40.7
	Salt	50 lb.	45.6
	Salt	60 lb.	59.6
	Dye	400 g.	74.0
2	Salt	50 lb.	52.8
	Dye	400 g.	75.0
3	Salt	50 lb.	42.0
	Dye	400 g.	63.5
4	Salt	50 lb.	70.8
	Dye	300 g.	77.0
	Dye	400 g.	80.5
	Dye	500 g.	76.0

Conclusions

Salt

The mean detention times determined with rock salt were not representative of the flow conditions which may be expected. All of the mean detention times determined with rock salt were greater than the theoretical time. Difficulty was encountered in performing the tests due to a highly fluctuating chloride content in the raw sewage. Chloride recovery was poor and inconsistent.

Fluorescein Dye

The mean detention times determined with fluorescein dye were most

representative of the flow conditions. All of the mean detention times determined with fluorescein dye were less than the theoretical time. The efficiency ratios were reasonably consistent, and dye recovery was consistently good.

Radiotracer

The mean detention times determined with rubidium^{86} radiotracer were less than theoretical, but varied more than was anticipated. Three of the efficiency ratios determined with rubidium^{86} were within 6 per cent of the efficiency ratios determined with fluorescein dye. Inconsistencies in the results from rubidium^{86} may have been due to the dosing procedure in which the radiotracers were mixed with water and poured directly into the flow at the clarifier inlet ports. This procedure may not have provided sufficient mixing of the radiotracer with the incoming sewage. As a result, much of the radiotracer may have been carried directly across the upper strata of sewage to the effluent weirs. Accordingly, the results of the radiotracer tests may not be representative of the flow conditions in the primary clarifiers.

Quantity Effect

The results of mean detention times determined with varied amounts of the same tracer were inconclusive. There is some indication that the mean detention time is lengthened by increasing the amount of rock salt used as a tracer. However, there is no indication that the mean detention time is lengthened by increasing the amount of fluorescein dye used.

Analytical Procedures

Analytical procedures adopted for determining the tracer content in the effluent samples were good and provided positive accurate results. The analysis of fluorescein dye samples was the most expedient.

Acknowledgments

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Industrial Wastes

TREATMENT OF PLATING WASTES FROM COMPUTER MANUFACTURING*

By L. J. Hosman and R. J. Keating

Respectively, Vice-President, Smith, Hinchman and Grylls, Inc., Detroit, Mich., and Manager, Industrial Waste Treatment Dept., Graver Water Conditioning Co., New York, N. Y.

When International Business Machines decided to do all its own plating and heat-treating work at Endicott, in order to achieve better control of quality, it was determined that the ultimate plant should provide good working conditions, safety, and every modern technique for improving work quality. The problem of designing such a plant proved to be especially complex because the computers, and other electronic equipment manufactured, require a wide variety of plating and heat treatment processes.

The success with which these objectives were attained is indicated in the selection of this plant as winner of "Factory Magazine's 1955 Significant Plant Award" (1). The citation reads in part as follows:

"For a manufacturing process in which corrosive liquids and fumes are inescapable, International Business Machines built a plant that sets a high mark for efficiency, appearance, civic responsibility and worker safety, health and comfort."

This paper reviews the chemical engineering factors involved in the treating of the cyanide and chromium plating wastes by ion exchange methods.

Building Design

The manufacturing building is a two-story structure, approximately 236 ft. by 270 ft. It was designed so that all operating equipment is located on the second floor and the service equipment, including that for waste treatment, is on the first floor. This separation of facilities simplifies operation and control and gives maximum flexibility for future expansion and rearrangement.

Plating Department

The plating department is equipped to provide every type of surface treatment required for the many complex assemblies used in the final product. Rinses from the automatic plating machines and from the still-rinse area are collected in covered polyvinyl chlorine-lined trenches, which also serve to carry away noxious fumes under suction. These are located under the plating room floor and discharge into large plenum chambers, also lined with polyvinyl chloride to prevent corrosion. These chambers run at right angles to the trenches. The plating wastes flow by gravity through the trenches to a plenum chamber below the operating floor, and then down to the waste treatment department on the first floor.

Heat Treating Department

The heat treatment department does not contribute substantially to the waste treatment problem since the quench-oils are filtered and cooled for re-use in a separate system. A con-

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siderable amount of salt cake is formed in the cyanide hardening process. The molten wastes, which is about 15 per cent cyanide in a carbonate salt, is cooled in special metal containers. The chunks thus formed are about a 6-in.-cube maximum, with a friability about that of limestone. Laboratory tests showed that this material could readily be dissolved with water, thereby simplifying disposal. These chunks are put into solution in perforated metal baskets lowered into an upflow dissolving tank equipped with an air grid for mixing. The baskets prevent any stray particles of metal from getting into the waste system. The overflow from this tank is discharged to the cyanide waste system.

Selection of Waste Treatment Methods

Prior to construction of the new plating waste and heat treatment building, highly toxic wastes from existing processes were given individual batch treatment. More dilute wastes from the industrial processes were discharged into a sewer which ultimately flowed, after further dilution, into the nearby Susquehanna River. Since production capacities were to be more than doubled by the new construction, it was recognized that existing methods of waste treatment would not be adequate to handle the increased volumes and concentrations of wastes involved. During the time the new facilities were being designed and constructed, the river in the vicinity of the plant outfall had not been classified. However, since the plant at Endicott is located in the center of a highly developed residential area, management insisted from the outset that, as part of its policy of being a good neighbor in the communities in which it is located, modern, effective waste treatment control be included in the planning for the new facility.

Field studies were made by the consulting engineer at the job site, in conjunction with the plant engineers. A number of waste treatment facilities handling similar wastes were visited. Special studies were also required because of the complexity and variety of the plating solution used for the specialized products manufactured. It was determined that the most advantageous method of handling the waste problem at this plant was by concentrating the dilute solutions by a system of ion exchangers and then destroying the concentrated exchangers regenerant by batch treatment (2).

This method was selected primarily for the following reasons:

1. Space for new construction was extremely limited and it was necessary to confine the waste treatment facility to the smallest possible area. The method selected provided the operating simplicity and positive control of a batch system without the need for the bulky holding tanks usually required for batch systems.

2. Chemical operating costs for this system, especially when credit was given for recovered chromic acid, were somewhat lower than the other systems considered.

3. A substantial part of the water used for plating rinses could be recovered for re-use—an important cost-saving feature. By reducing the demand for raw water a real contribution could be made to conservation of the local water table. This also furnished an opportunity to demonstrate how a large industrial plant can produce quality work without excessive demands on local water supplies.

4. The waste system would also provide the demineralized water needed for the quality rinsing stages.

Waste Disposal Area

Flow Characteristics

Total flow to the waste treatment plant is approximately 1,200 g.p.m., of which 865 g.p.m. represents waste rinse flows and 350 g.p.m. is the maximum

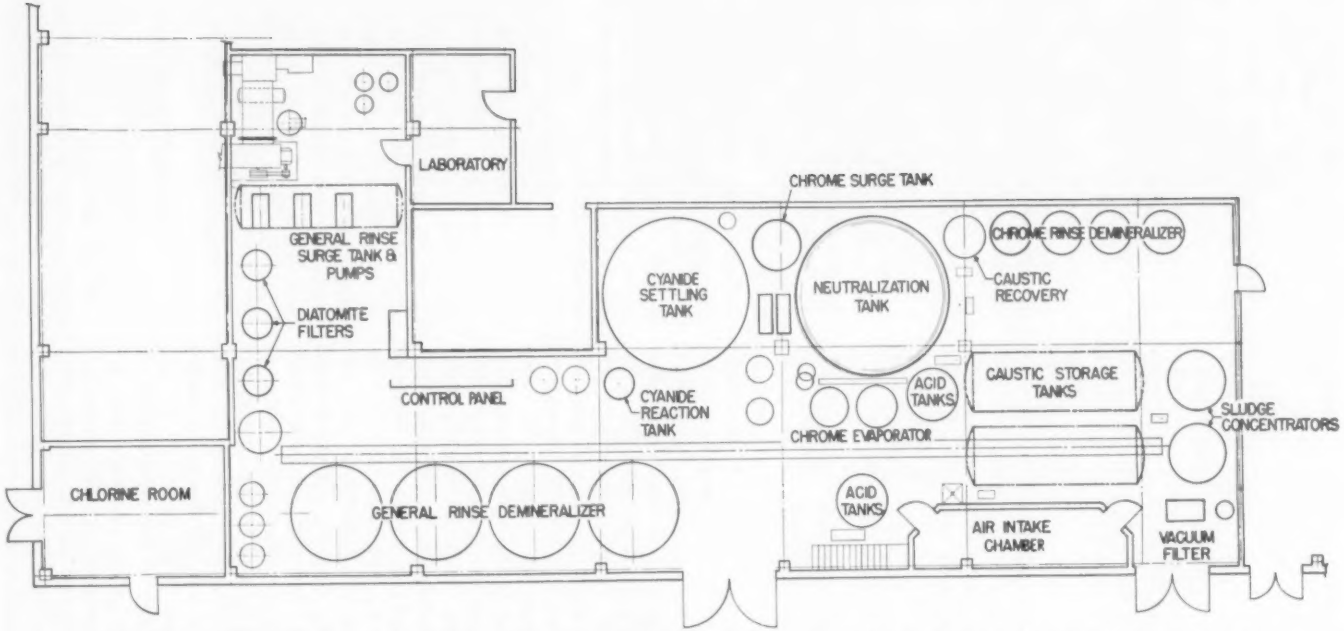

FIGURE 1.—Simplified schematic layout of the waste treatment facility, International Business Machines, Endicott, N. Y.

supplemental make-up water. The bulk of this flow is in the form of general plating rinses which are free of chromium and cyanide compounds.

It was decided to treat the chromium-bearing rinses separately from the general rinses in order to avoid possible contamination of other sensitive plating baths with chrome leakage through the ion exchange units. The metallic cyanide rinses were handled separately to avoid ion exchange fouling and subsequent resin deterioration.

Design Plan

The over-all plant, as finally laid out, was designed to:

1. Discharge into the Susquehanna River a substantially waste-free water that more than met state requirements and would contain less than:

Free cyanide	0.1 p.p.m.
Trivalent chromium	3.0 p.p.m.
Hexavalent chromium	1.0 p.p.m.

The effluent from this waste treatment plant was to conform to the New York State Department of Health standard classification "B," recreational designation.

2. Recover as much as possible of the valuable chromium from the chrome-plating rinse system for re-use in the chrome baths.

3. Provide demineralized water for use throughout the plating department to improve bath and rinsing quality and thereby cause fewer rejects than occurred with the make-up water previously used.

Rinse water from the various plating operations flows through a system of trenches, located below the plating tanks on the operating floor, to three separate run-off systems. As mentioned previously, these same trenches also serve to conduct noxious fumes from the plating tanks to a fume washer system so that the air exhausted is safe for discharge to the atmosphere.

Liquid flow from each of the three main trench systems is directed into a separate surge tank which serves the primary purpose of venting all poisonous gases and entrapped air to the gas washer system. These surge tanks also serve partially to equalize flow and concentration variations ahead of the treatment system. A simplified layout of the waste treatment plant, showing the various items of equipment and flow discussed, is shown in Figure 1.

Since this new manufacturing building was located in a residential area, over-all construction space was limited and the space available for the waste treatment area was only 5,280 sq. ft. Detailed studies and considerable ingenuity finally resulted, not only in an attractive and efficient layout, but in one which also provided necessary aisle space for convenient operation, chemical handling, and employee safety.

The over-all plant consists of the following basic systems:

1. Filters and demineralizer for general rinse treatment.
2. Demineralizer and evaporator for chrome recovery.
3. Continuous cyanide destruction.
4. Batch neutralizing.
5. Sludge handling.
6. Master control panel for automatic regeneration and monitoring of the systems.

General Rinse System

Equipment

The general rinse system (Figure 2) is designed for a flow of 890 g.p.m. Of this, 540 g.p.m. consists of rinse waters exclusive of those wastes bearing cyanide or chromates returned to the system from the plating room. A maximum of 350 g.p.m. of supplementary make-up water from the municipal water supply is permitted. Exclusive of the controls and auxiliaries, the equipment involved consists essentially of the following units:

1. General rinse surge tank, 5 ft. in diameter and 19 ft. in length.
2. Three septa-type filters, 42 in. in diameter.
3. Two cation exchange units, 11 ft. in diameter and 8 ft. in length.
4. Two anion exchange units, 11 ft. in diameter and 8 ft. in length.
5. Main demineralized water clearwell, 47,500 gal. capacity.
6. Emergency acid waste clearwell, 37,800 gal. capacity.

Operation and Safeguards

Under normal operating conditions, the running rinses from the plating room are discharged into the surge tank, which is equipped with proper vents to the fume washing system to permit discharge of noxious gases and entrapped air. However, if the dissolved solids concentration in the incoming rinses increases above a predetermined point, due to a bath dump, a conductivity controller automatically by-passes this flow to the emergency acid clearwell. This precaution is necessary to prevent contamination of the anion unit, which might result from high concentrations of hydrogen or sodium ions partially regenerating the cation resin during the service run and releasing high concentrations of metal ion which would precipitate in the high

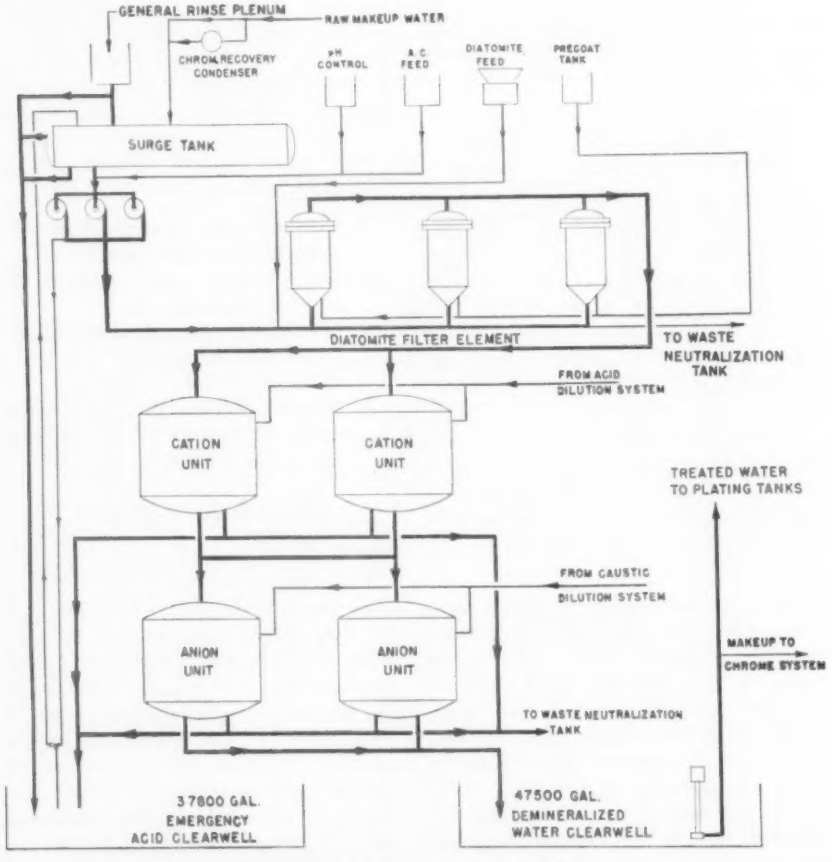

FIGURE 2.—General rinse system.

pH environment of the anion resin (3). If such a diversion of the rinse flow occurs, the supply of make-up water to the surge tank is automatically increased to compensate for the decrease in waste flow, preventing a shortage of demineralized water to the running rinses in the plating room.

Provision is made so that any emergency overflow from the surge tank is also diverted to the emergency acid clearwell. Cooling water from the condenser on the chromic acid evaporator flows into the surge tank to minimize the demand for make-up water. Concentrated solutions in the emergency acid clearwell are diluted with low solids waste waters from the ion exchange regeneration cycle and transferred, when convenient, to the surge tank in preference to the use of make-up water.

Removal of Organics

From the surge tank, the waste is pumped through three activated carbon-diatomite septa filters. This is done because preliminary investigation had disclosed that these rinses would contain approximately 50 p.p.m. turbidity and measurable amounts of organic matter from the nickel plating and cleansing baths. The latter caused concern because experience at other plants showed that such organics, particularly in the concentration expected here, caused serious fouling and capacity loss of the resins used in ion exchange (4)(5). Studies had demonstrated that the bulk of the troublesome organics could be selectively removed by activated carbon filtration. Consequently, at Endicott an especially prepared mixture of activated carbon and diatomite is used as a coating and body feed for the filters. The body feed is provided to reduce pressure drop and permit longer filtration runs. Since low flow through the filters might cause accidental loss of filter cake, a low-flow alarm is provided to signal the operator to switch from service flow to recycle when this condition occurs.

Ion Exchange Units

Water from the filters passes through the cation exchangers until the service run is terminated on an alarm signal which operates when a predetermined metered gallonage is reached. Regeneration is then initiated by a push-button control which actuates an automatic series of regeneration stages. Two-step acid regeneration is used, with the regenerant acids going to the neutralization tank while the dilute rinses are diverted to the emergency acid clearwell. Water required for the various regeneration stages is taken from the general rinse surge tank in order to conserve the use of municipal water. Required acid for regeneration is drawn from an outside storage tank to an acid-measuring tank and thence to a dilution tank with an air-grid mixer, which is vented to the fume washer system.

Flow from the cation units goes to the anion exchangers. The end of the service run on these units is signaled by a conductivity alarm on the master control panel; however, the unit remains in operation until stopped by the operator. Automatic regeneration of the unit is initiated by a push-button control. A two-stage rinse is used with the first step going to the neutralization tank with the spent caustic regenerant, while the dilute second step with the backwash water goes to the emergency acid clearwell for reuse. Cation effluent is used for all regeneration steps to prevent contamination of the resin. Caustic is drawn from two 50-per cent caustic storage tanks which are 7 ft. in diameter and 23 ft. in length.

Demineralized water from the anion exchangers is stored in the general rinse demineralized water clearwell. It is pumped as required to the general and cyanide rinse tanks and baths in the plating department, with a portion diverted for water make-up to the chrome system.

All controls for the automatic ion

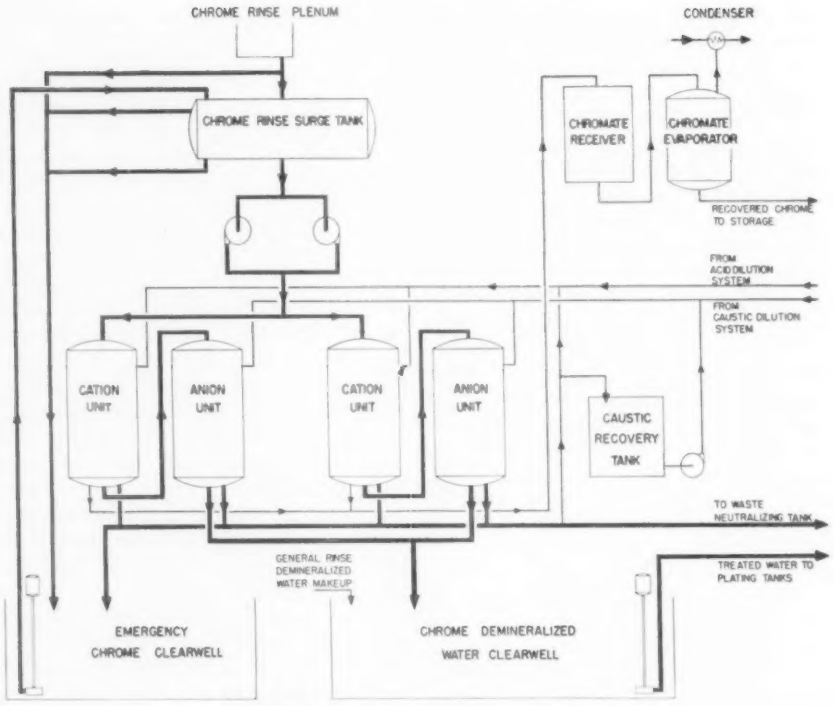

FIGURE 3.—Chromate recovery system.

exchange regeneration and effluent quality control monitoring are mounted on one section of the master control panel.

Chromate Recovery System

Equipment

The chromate recovery system (Figure 3) is designed to handle a rinse flow of 150 g.p.m. The essential equipment involved consists of the following:

1. Surge tank 6 ft. in diameter and 8.5 ft. in length.
2. Two cation exchange units 5 ft. in diameter and 11 ft. in length.
3. Two anion exchange units 5 ft. in diameter and 11 ft. in length.
4. Caustic recovery tank 5 ft. in diameter and 7 ft. in length.
4. Chromate evaporation and recovery system.
6. Chrome demineralized water clearwell, 26,800 gal. capacity.
7. Emergency chromate clearwell, 16,500 gal. capacity.

Operation

In normal service operation, water containing chromate is pumped from the chromate surge tank through the cation unit and then through the anion unit to the chromate demineralized water clearwell. A pump, taking suction from the clearwell, pumps this demineralized water to the various tanks in the plating department. The effluents from the rinse tanks are collected in a system of pipes and trenches which return them to the chromate surge tank.

Safeguards

The chrome surge tank is vented to the fume washer, as previously de-

scribed, for the general rinse system. If the chromic acid concentration reached a point where serious oxidation of the organic exchange resin might result, the flow would automatically be diverted to the emergency chrome clearwell. Any overflow from the surge tank is also discharged to the emergency chrome clearwell. Supplementary water required to make up evaporation losses in the plating room is supplied automatically from the general rinse demineralizer clearwell to the surge tank when the water level in the chrome demineralizer falls.

Ion Exchange Units

The waste water from the surge tank is pumped through the ion exchange units which are set up in cation-anion pairs for train operation. The end of the service run is indicated by high conductance on a conductivity controller on the effluent of each anion unit. When the conductance of the effluent reaches the shut-off point, an alarm signals the operator to push a button which takes both the cation and anion units of that train out of service and starts them through the regeneration cycle. All of the stages of the regeneration cycle on this system are carried on with demineralized water or chrome rinse to prevent contamination of the recovered chrome and discharge of any toxic chromium wastes to the sewer.

During the regeneration of the anion unit, only that portion of the regenerate effluent which is high in chromate content is sent to the cation exchange unit. Other portions of the regenerate effluent are diverted either to the emergency chromate clearwell or to the caustic recovery tank. Use of this "split regeneration" method (6) substantially reduces anion regeneration operating costs and reduces the volume of water to be distilled in the evaporator, further reducing costs and permitting the use of a smaller evaporation system. The chrome-rich regenerate effluent passing through the cation exchanger is converted to chromic acid and automatically diverted to the chromate receiving tank. In the meantime, the ion exchange train is automatically returned to service until the next regeneration step.

The contents of the chromate receiving tank are drawn to a glass-lined evaporator for further concentration of the valuable chromic acid. The recovered vapors, which may contain some dilute chromic acid, are condensed and discharged to the emergency chrome clearwell. Municipal water is used for cooling the condenser and then discharged into the general rinse surge tank in order to prevent wasting water. The recovered chromic acid is drawn from the evaporator and discharged to storage.

Cyanide Destruction System

The cyanide destruction system (Figure 4) is a continuous treatment system designed to handle 175 g.p.m. of cyanide-bearing wastes. Approximately 160 g.p.m. come from the heat-treatment system and plating room trenches and 15 g.p.m. are drawn from the fume-washer circulation system. The cyanides from the plating operation are primarily from copper cyanide running rinses and are supplemented by rinse dip overflows from the heat treatment operation and dissolved cyanide cake from the cake-dissolving tank previously described.

Equipment

Principal equipment involved consists of the following:

1. Cyanide surge tank, 42,500 gal. capacity.
2. Cyanide reaction tank, 42 in. in diameter and 7 ft. in height.
3. Cyanide settling tank, 18 ft. in diameter and 10 ft. in height.
4. Gas chlorinator, 2,000 lb. per day capacity.
5. Redox and pH control system.

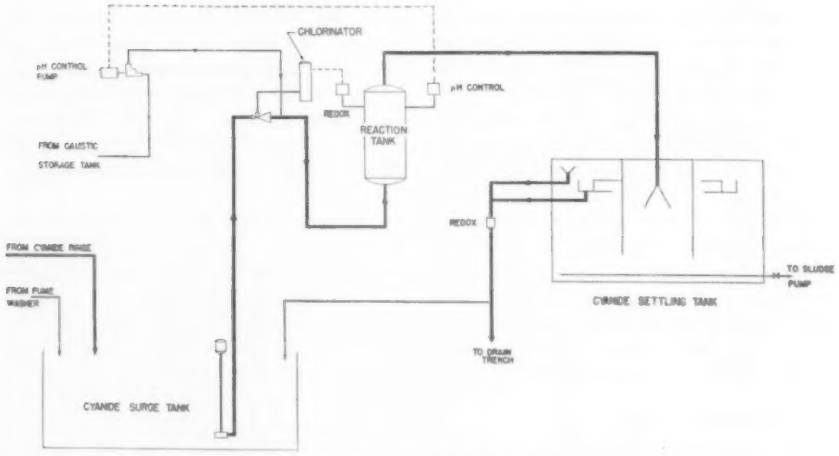

FIGURE 4.—Cyanide destruction system.

Because of space requirements in the waste treatment area, it was decided to use a continuous-destruction system for the cyanide compounds. The alkaline chlorination system is used to convert all cyanides to cyanates. Provision is included in the system to permit complete destruction to CO_2 and N_2 if it should prove to be desirable at a later date.

Operation

All cyanide-bearing wastes flow by gravity into the cyanide surge tank. A large surge tank is required in this instance in order to equalize the widely varying concentrations of cyanide and permit better automatic control of the operation. For this reason, provision for continuous recirculation of the cyanide waste has been made.

The cyanide wastes are pumped through the gas chlorine eductor to the cyanide reaction tank. Sodium hydroxide, metered by a pH controller, is fed to this stream. The reaction tank provides a total retention time of approximately 3 min. Samples are taken from the tank for redox control of chlorine injection and pH control of sodium hydroxide injection. Since it is desired to restrict the oxidation reaction to the cyanate in this instance, the pH of the reaction is maintained at about 11. At this pH the reaction of cyanide to cyanogen chloride is instantaneous and the hydrolysis of cyanogen chloride to cyanate is very rapid. On the other hand, the reaction of the cyanate to CO_2 and N_2 is negligible at this pH, even in the presence of excess chlorine (7). Consequently, the redox control can function, based on the varying concentration of cyanide to be treated, without the complication of side reactions.

The treated solution from the reaction tank flows through the downcomer of the settling tank to the settling area. The entire top of this tank is covered and vented to the fume washers to prevent accumulation of any noxious fumes. As the cyanide complexes are destroyed the available alkalinity precipitates the copper and other metallic ions present as a hydroxide sludge. The treated solution, which is now free of toxic components, is overflowed to the storm sewer.

Another redox instrument monitors the treated water so that if there is any failure in the automatic treatment system, an alarm signals the operator to return the effluent to the cyanide surge tank for retreatment. A sample line is diverted through a fish tank

mounted on the master control panel with the other system monitors to give visual control of the effectiveness of treatment. In addition, regular samples are submitted for laboratory analysis.

The hydroxide sludge is drawn from the bottom of the settling tank and pumped to either of two sludge concentrators in the sludge handling system. The cyanide destruction system is a steady-flow, self-monitoring process which operates with minimum operator attention.

Neutralizing System

A neutralizing system (Figure 5) is provided to neutralize the waste acid resulting from regeneration of the cation units in the general rinse system and the chrome recovery system and the caustic resulting from the anion regeneration in the general rinse system. The neutralizing tank is 17.5 ft. in diameter and 21 ft. high and is equipped with air mixers, samplers and a sludge draw-off system.

One complete regeneration of each of these systems, when brought together in the neutralizing tank, will produce a solution having a pH value of approximately eight, which gives good precipitation of metallic hydroxides and a water suitable for discharge. Provision is made for adjusting the pH to this value, if required. The air mixing is provided to insure complete reaction.

Once air mixing has been completed, the tank is allowed to remain quiescent for 4 hr. in order to insure complete precipitation of metallic hydroxides. Sludge is then pumped to either of two sludge concentrators and the supernatant water is discharged to the storm sewer.

Sludge Handling System

The sludge handling system provides a method for concentrating sludges derived from the various processes. Equipment involved consists primarily of:

1. Two cone-bottom sludge concentrators, 7 ft. in diameter and 7 ft. in height.
2. Pre-coat vacuum filter.

Sludges from the neutralizing tank and the cyanide settling tank are pumped to one of the two sludge concentrators. These concentrators are

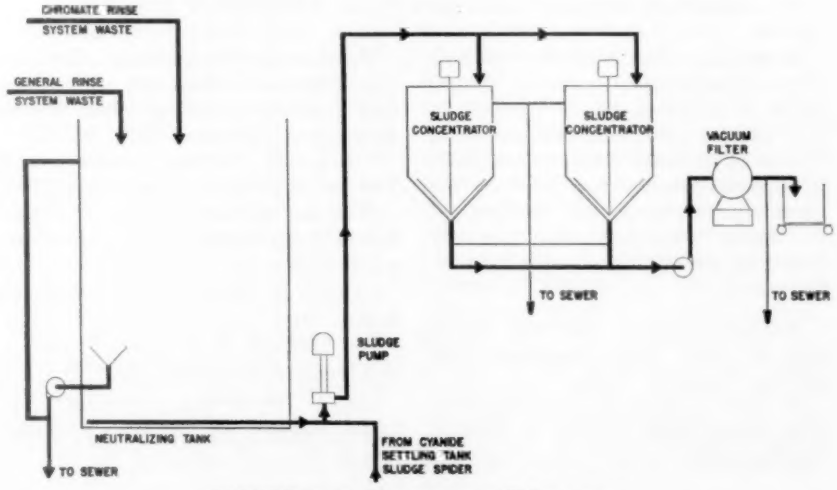

FIGURE 5.—Acid waste neutralizing system.

equipped with conical bottoms and thickening rakes to further thicken and concentrate the mixed sludge. The dense sludge is then pumped to a vacuum filter which has been precoated with a diatomite filter aid. A doctor blade removes the dewatered sludge from the filter at a moisture content which permits easy handling. The sludge is hauled away by truck to a suitable disposal area.

Acknowledgments

The cooperation of the Plant Engineering Division and of other staff engineers of International Business Machines in the coordination and planning of this project is gratefully acknowledged, as is the assistance rendered by various members of Smith, Hinchman and Grylls, Inc., and the Graver Water Conditioning Co., in the design and engineering phases of the work. In addition, the authors wish to express appreciation to Sordoni Construction Company, Builders, of Wilkes-Barre, Pa., and Mance Corporation, mechanical contractors, of New York City, N. Y., who participated in a major way in the completion of this project.

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WATER POLLUTION CONTROL ADVISORY BOARD

A national citizens group will help shape Federal water pollution control policy as provided for in Public Law 660. Eight prominent citizens, long interested in water conservation problems, were recently appointed by the President to serve as members of the Water Pollution Control Advisory Board of the Public Health Service. They are:

Milton P. Adams, Executive Secretary, Michigan Water Resources Commission, Lansing, Mich.

Dr. Daniel Bergsma, Commissioner, New Jersey State Board of Health, Trenton, N. J.

Morrison B. Cunningham, Assistant City Manager, Oklahoma City, and Past President, American Water Works Association, Oklahoma City, Okla.

Charles H. Elston, Attorney and Member of Congress, Cincinnati, Ohio.

William Galbraith, Chairman, Washington State Pollution Control Commission, Olympia, Wash.

Charles R. Hook, Board Chairman, Armco Steel Corp., Middletown, Ohio.

Dr. Howard P. Sawyer, Physician and Surgeon, Sanbornville, N. H.

Carl D. Shoemaker, Co-founder, National Wildlife Federation, Washington, D. C.

METAL–FINISHING AND BRASS MILL WASTES

By Merwin E. Hupfer

Senior Sanitary Engineer, Connecticut State Water Commission, Hartford, Conn.

Large quantities of metal products are manufactured in Connecticut, and the treatment and disposal of waterborne wastes from the metal-finishing, steel, and brass industries constitute a major problem. These wastes, which are chiefly inorganic in nature, are extremely poisonous to aquatic life, corrosive to sewers, and have a pernicious effect on biological sewage treatment processes because of their toxicity. The tolerable limits of their several components are usually much lower than for organic wastes. After many years of laboratory research and pilot-plant study, several good, reasonable, and equitable methods of treating these three types of wastes have been developed. Many of the treatment processes are presently being used by industry and a few have yet to be employed on a full-scale basis.

Metal-Finishing Wastes

The industrial wastes from metal-finishing operations contain acids, alkalies, cyanide, and metals such as copper, zinc, nickel, cadmium, and chromium. Concentrations of these various constituents vary widely from plant to plant depending on the amount of drag-out, the volume of production, and the frequency of spent solution dumping.

Processes

The metal-finishing processes producing contaminated wastes can be divided into three groups: stripping, cleaning, and plating.

Stripping processes are used for the removal of defective plating, scale, rust, and other coatings on the material to be plated. The type of process used depends on the coating to be removed and the base metal involved. The most common processes are acid baths, generally hydrochloric, sulfuric, nitric or hydrofluoric acids, having a concentration ranging from 5 to 10 per cent acid. Occasionally, alkaline baths are used.

Cleaning processes, which are performed to remove large amounts of oil, grease, buffing compounds, drawing compounds, and the like, generally consist of three types: organic solvent vapor cleaners, alkaline cleaners, and acid pickling cleaners. Organic solvent vapor cleaners remove only the grease and oil and do not materially contribute to industrial waste. Alkaline cleaners consist of alkaline soaking cleaners, alkaline electro-cleaners and organic emulsion cleaners. Acid pickling cleaners are generally employed for surface preparation and to neutralize the alkaline cleaners previously used. They usually consist of sulfuric, hydrochloric or nitric acid ranging in concentration from 1 to 5 per cent acid.

Electroplating is the process in which a thin coating of metal is deposited on the product, which is made the cathode in an electrolytic cell. Flow diagrams for four common types of automatic plating machines are shown in Figure 1. The stripping operation, which is not always required, does not appear on these diagrams. A manual operation may have fewer rinses, since one rinse may be used after several solutions. The volume of the solutions ordinarily varies from 50 gal. to several thousand gallons.

FIGURE 1.—Flow sheets for common types of automatic plating machines. (Wastes overflowing to final effluent are indicated by an arrow.)

Sources of Wastes

The major sources of wastes in a metal-finishing plant are drag-out and solution dumping.

Drag-out is the solution carried out of a bath and into a rinse by the material and the racks holding the material. The amount of drag-out varies considerably, depending on: (a) the bath concentration and temperature, (b) the size and shape of the material being processed, (c) the position in which it is mounted on the racks, (d) the time it is allowed to drain, (e) the shape and coating of the racks, and (f) the number of pieces being processed. Drag-out is usually found to be greater in manual than in automatic plating.

The dumping of spent stripping and cleaning solutions is very prevalent, sometimes as often as once a week. Plating solutions are usually reclaimed and re-used as often as possible before dumping, although some industries are known to dump the baths weekly. Because of their extreme toxicity, strong solutions cannot be dumped directly

into sewers or streams. They should either be bled into the weaker rinse waters and treated with them or discharged to seepage lagoons well removed from watercourses and potable water supplies.

Character and Strength of Wastes

The character and strength of metal-finishing wastes vary greatly; however, they do have some general characteristics. The wastes will usually contain low concentrations of metals such as copper, zinc, chromium, nickel, and cadmium in solution as simple ions or cyanide complexes. An excess of sodium or potassium cyanide and some of the base metal ion, which has been dissolved in the stripping or cleaning processes, will also be present in the wastes.

As an example of the relative strengths of the various metals which might be found in a plating room effluent, it can be assumed that a plant has the four automatic plating machines previously shown in Figure 1 with one change, no recovery rinse following the chrome solution. Each of the 22 running rinses flows at a rate of 4 g.p.m., giving a total flow of 42,240 gal. per 8-hr. day, and the rate of drag-out from each plating bath is 2.5 gal. per hour, which is thus diluted 96 times by the running rinse. The common chromium plating bath contains 53 oz. per gallon of chromic acid from which the total chromium concentration is computed to be 207,000 p.p.m. The concentration in the running rinse will be 1/96 as great or 2,160 p.p.m. When mixed with the other rinses, it is further diluted 22 times, giving a total chromium concentration in the plant effluent of 98 p.p.m. Similar computations for cyanide and the other metals present would show concentrations in the plant effluent of 23 p.p.m. cyanide, 39 p.p.m. nickel, 14 p.p.m. copper and 16 p.p.m. zinc.

Some analyses of actual metal-finishing effluents are shown in Table I. It should be noted that effluents can be acidic or alkaline, depending on the type of baths being used. The volume of this type of waste varies from plant to plant. In Connecticut the range is from 2,000 to 500,000 g.p.d.

In-Plant Pollution Reduction

There are several means by which a manufacturing plant can reduce its pollution load and at the same time make substantial financial savings in plating and treatment costs. One method is by the reduction of drag-out losses through: (a) the proper racking of parts for fast draining, (b) the scheduling of sufficient time for good draining, (c) the use of smooth racks, and (d) the use of stationary recovery rinses following all plating baths. Recovery rinses not only greatly reduce the amount of drag-out but also, as their name implies, recover the drag-out solution so that it may be used as make-up in the plating baths. In some

TABLE I.—Metal-Finishing Waste Concentrations

Plant	pH	Copper (p.p.m.)	Nickel (p.p.m.)	Zinc (p.p.m.)	Cadmium (p.p.m.)	Chromium (p.p.m.)		Cyanide (p.p.m.)
						Cr^{+6}	Total	
A	4.5	1.3	24	13	1.4	87	—	12.6
B	5.9	1.0	—	—	420	3.2	51	36
C	2.4	35	—	—	—	555	612	1.2
D	3.2	16	0	0	—	0	1.0	6
	10.4	19	0	0	—	0	0.5	14
E	10.5	6	25	39	—	—	—	10
F	7.1	0.3	11	0	0	2.5	6.8	0.4

instances it has been found that the use of one or more rinses can reduce the metal concentration in the first running rinse to a point where it does not require treatment.

Another method is by reducing water consumption to a minimum. This can be done by employing (a) countercurrent rinsing, (b) parallel rinsing, (c) spray rinsing, (d) spray and dip rinsing, and (e) air agitation in rinse tanks.

Ion exchange is a relatively new process for recovering chemicals from rinse waters. Use of this method for recovering metals from copper, nickel and chromium wastes has been successful and studies are in progress on cyanide wastes.

By maintaining accurate chemical control over plating baths, the dumping of these solutions can be kept at a minimum.

Methods of Treatment

Metal-finishing wastes can be treated most expediently if they are separated into acid-chromium wastes and alkaline-cyanide wastes, since the most effective treatment methods for the two types are different. Both of these wastes might contain several metals in varying concentrations. Furthermore, the possibility of acidification of cyanide wastes by the acid wastes forming toxic hydrogen cyanide gas must be avoided.

Treatment plants can be batch-type, flow-through, or a combination of both. The batch method is most economical for smaller flows and is superior for purposes of control. Flow-through plants are now possible because simplified automatic pH controls are available.

The treatment of the acid-chromium wastes consists of (a) lowering the pH to between 2.0 and 3.0, (b) reducing the chromium from the hexavalent to the trivalent form so that the total chromium will precipitate, (c) raising the pH to 8.0 or above to neutralize excess acidity and precipitate the chromium and any other heavy metals present as hydrous oxides. Sulfuric acid is used to lower the pH. The most popular chromium reducing agents are sulfur dioxide and ferrous sulfate. However, sodium metabisulfite, barium sulfide, and several other agents are being used successfully. Lime or sodium hydroxide is generally used for the neutralization and precipitation of metals. If chromium is not present only the precipitation step is necessary.

Alkaline-cyanide wastes are treated by destroying the cyanides and precipitating the metals present as hydrous oxides. The most frequently used methods of destroying cyanides are acidification and aeration, and alkaline chlorination. Ponding of cyanide wastes and depending on natural aeration is a simple method, but because of the time and area requirements and the dangers accompanying the liberation of hydrogen cyanide gas, it is not generally satisfactory. Acidification in a closed unit with forced aeration, the fumes being exhausted through a high stack, has been found feasible in some instances (1), but as in ponding, the time required and the formation of hydrogen cyanide, together with the high installation costs, make this method objectionable. Alkaline chlorination appears to be the best method yet devised. It lends itself to both batch and flow-through treatments; however, here again the batch method provides for better control. While the cyanides are being oxidized by chlorine, a pH of 8.5 or higher must be maintained by the addition of lime or sodium hydroxide. Fortunately, the pH of the wastes is then at the level necessary for the precipitation of the metals.

Should cyanides not be present in the wastes, the acid-chromium wastes can be reduced and then mixed with the alkaline wastes, thus giving partial neutralization and requiring less chem-

icals for precipitation of the metals. On the other hand, should there be no chromium in the wastes, the cyanide can first be destroyed, and the acid and alkaline wastes then mixed preparatory to metal precipitation.

If there are appreciable amounts of floating oil present in the wastes, they can be removed by a skimming device in the precipitation unit. Sludge can be hauled to a suitable disposal area either in its liquid state or after having been dewatered on sand beds or lagoons.

Steel and Brass Mill Wastes

Steel and brass mills manufacture plates, sheets, and strips by rolling, rods and wire by extrusion and drawing, and tubes by piercing, or extrusion and drawing. The major constituents in waterborne steel mill wastes are acids and iron, and those in brass mill wastes are acids, chromium, zinc, and copper. As in metal-finishing wastes, the concentration of these wastes in the total effluent will vary, depending on the amount of drag-out, quantity of material processed, and the frequency with which spent strong solutions are dumped.

Processes

During the manufacture of steel and brass products, the material is subjected to intense heat in the extrusion and annealing operations, which forms a very hard oxide scale on the surface of the metal. The scale thus formed and, in the case of steel, the red rust which accumulates on long exposure to the air, must be removed before the rods, tubes, and wire are drawn. This precaution is necessary to avert damage to dies, and before plates, sheets and strips are rolled so that the scale will not be embedded in the finished product. Scale and rust removal is accomplished by immersing the material in a bath of 5 to 10 per cent sulfuric acid by volume. This process is commonly called "pickling." Sulfuric, hydrochloric, nitric, hydrofluoric, and phosphoric acids and combinations thereof are employed in pickling steel, depending on the product being treated. Sulfuric acid accounts for more than 90 per cent of the acid used (2).

Stains are also formed on brass and must be removed, especially from the finished product. To achieve this the material is placed in a "bright-dip" solution containing 5 to 10 per cent sulfuric acid and 0.25 to 0.5 lb. of sodium dichromate per gallon of solution. After the material has remained in the pickle or bright-dip solution for the necessary length of time, it is removed and dipped in continuously flowing rinse tanks.

Source, Strength, and Character of Wastes

The chief sources of waterborne industrial waste in mills are the dilute rinse waters and the dumping of spent strong solutions.

During pickling and bright dipping, some of the scale and base metal are dissolved, causing a decrease in the sulfuric acid concentration and an increase in the dissolved metal concentration. These solutions are strengthened from time to time by the addition of acid and dichromate. As the metal concentration increases, the pickling and bright-dipping time likewise increase. When a certain concentration of metal is reached, the solutions are dumped and replaced by fresh solutions. In general, bright-dip baths are dumped after a few days of use, whereas pickle baths can be used for about a month before dumping becomes necessary.

The pollution load from mills can be reduced by the use of reducing atmosphere annealing, multiple draw benches, and the several methods previously discussed under metal-finishing wastes.

In 1940, the Connecticut State Wa-

TABLE II.—Characteristics of Brass Mill Wastes

Item	Concentration				
	Pickle Tube (g./l.)	Bright-Dip Tanks (g./l.)	Rinse-Water Drains (p.p.m.)		
			Tube Mill	Rod and Wire Mill	Rolling Mill
Sulfuric acid	59.7–163.5	5.6 –85.8	4–209	192–4,942	140–1,997
Copper	4.0–22.6	6.9 –44.0	34–147	385–1,582	10– 87
Zinc	4.3–41.4	0.2 –37.0	19– 73	350–4,300	28– 112
Chromium:					
Hexavalent	—	4.3 –19.1	0– 5	0– 67	0– 35
Total	0– 0.56	13.5 –47.7	3– 78	345–1,100	6– 84
Iron	0.1– 0.21	0.03– 0.36	1– 5	9– 93	1– 13

ter Commission made a survey at a brass mill to determine the characteristics of the wastes from the pickling and bright-dip processes. The results of this survey are shown in Table II. Calculations made from these analyses and the respective volumes of the wastes showed that the rinse waters contained 88.5 per cent of the acid and 90 per cent of the total metals lost, whereas the spent solution dumps contained only 11.5 per cent of the acid and 10 per cent of the total metals lost. This information has resulted in the placing of more emphasis on the handling of dilute wastes in the solution of treatment problems.

Wastes from steel mills can be expected to have about the same concentrations of acid and metal as brass mill wastes, although they contain iron rather than copper and zinc, and there is no chromium present.

Methods of Treatment and Recovery

Steel Mill Wastes

The most practical method yet devised for the treatment of steel mill rinse waters is to neutralize the free acid and precipitate the iron with lime. If spent pickle liquors are to be treated with the dilute wastes, they should be collected separately in a holding tank and fed into the rinse stream at as even a rate as possible to avoid great fluctuations in the concentration of the mixture. The iron oxide sludge from this treatment is usually disposed of by lagooning. Some industries have found it economical to recover ferrous sulfate from the spent pickle liquors. This can be accomplished by storing the liquor in acid-resistant tanks where cooling and crystallization will occur. The ferrous sulfate crystals (copperas) are of salable quality and the remaining liquid, sulfuric acid, can be re-used in the acid vats. There are several drawbacks to this method of handling spent liquors, namely: copperas cannot be shipped far economically, its market value fluctuates, and the supply greatly exceeds the demand.

Brass Mill Wastes

For many years the Connecticut State Water Commission and the Sterling Chemistry Laboratory of Yale University have studied numerous methods for the treatment of brass mill wastes and the recovery of valuable by-products on both laboratory and pilot-plant scales. The most satisfactory method devised to date for treating the rinse waters is shown in Figure 2. In addition, the method provides for the recovery of chromium, zinc, and copper from the filter cake (3). Briefly, this method consists of the following steps:

1. The wastes are equalized to minimize large fluctuations in metals concentration.

2. Sulfur dioxide is added to reduce the chromium from the trivalent to the hexavalent form in order to precipitate the total chromium.

3. Lime or soda ash is mixed with the wastes to neutralize them and to precipitate chromium, copper, zinc, and other alloy metals present in minor quantities.

4. Effluent from the settling tank is discharged to the receiving stream.

5. The sludge is dewatered on a vacuum filter.

6. Soda ash is added to the dewatered sludge and the mixture is roasted in a gas-fired furnace to oxidize the chromium to the hexavalent form.

7. Sodium chromate, in a form usable in bright-dip operations, is leached out of the clinker with water.

8. The remaining sludge is dissolved with sulfuric acid.

9. Copper is deposited on brass chips in the presence of chloride. (The zinc in the chips is replaced by copper.)

10. Zinc dust and zinc oxide are added at the purifier to raise the zinc concentration.

11. This waste is filtered and zinc is extracted as electrolytic zinc.

12. The remaining liquid, containing sulfuric acid, is re-used to dissolve the sludge.

A process has also been developed for the regeneration of strong chromate waste pickle liquor which is very similar to the recovery method just described. Several difficulties are inherent in these recovery processes, and further pilot-plant studies will be required. However, none of the problems appear to be insurmountable.

Toxicity to Aquatic Life

Acids, cyanides and metals in solution are very toxic to aquatic life, even in small concentrations. It is generally considered that an acid concentration continually remaining below pH 6.0 in a receiving stream is lethal to certain forms of aquatic life on which fish feed and thus is lethal to fish. Concentrations of copper, zinc, chromium, nickel, and other metals greater than approximately 2 p.p.m. and cyanide concentrations, greater than 0.5 to 2 p.p.m., depend-

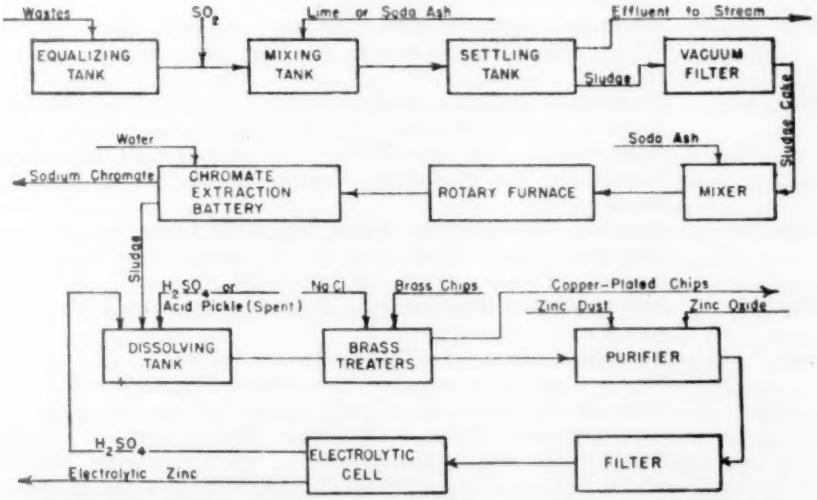

FIGURE 2.—Flow diagram for the treatment of brass and copper mill wastes.

ing to some degree on the hardness of the water, are generally considered lethal to aquatic life.

Effect on Sewers and Sewage Treatment Processes

When metallurgical wastes exceeding certain concentrations are discharged into sewerage systems, they have a deleterious effect on the sewers and the sewage treatment plants. These wastes will corrode concrete sewers, eventually causing their collapse. At the sewage treatment plants, these wastes will destroy concrete and corrode the mechanical equipment. The various waste chemicals also have an adverse effect on sewage treatment processes because of their toxic effect on the biological organisms of purification. In anaerobic digestion, gas production is reduced. Nitrification is retarded, and in some instances entirely stopped in aerobic processes. The effective control and treatment of metallurgical wastes is essential.

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MEETINGS OF INTEREST

1957

Jan. 29–31 **Radiological Health Seminar,** School of Public Health, University of North Carolina, Chapel Hill, N. C. Associate Professor Marvin L. Granston, Dept. of Sanitary Engineering, University of North Carolina, Chapel Hill, N. C.

Feb. 18–22 **American Society of Civil Engineers,** Jackson, Miss. W. H. Wisely, Executive Secretary, 33 West 39th St., New York 18, N. Y.

Mar. 4–8 **Bavarian Biological Institute,** Munich, Germany. Introductory course on biology of sewage and stream sanitation. Registration closes Feb. 25. Fee $10 (50 DM). Dr. H. Liebmann, Bayerische Biologische Versuchsanstalt, Veterinärstrasse 13, Munich 22, Germany.

Mar. 5–9 **American Concrete Pipe Association,** 49th Annual Convention, Shoreham Hotel, Washington, D. C. Howard F. Peckworth, Managing Director, 228 North LaSalle St., Chicago 1, Ill.

Mar. 11–14 **Second Nuclear Engineering and Science Conference,** Philadelphia, Pa.

Apr. 1–12 **Residential Course on Trade Wastes,** University of Durham, King's College, Newcastle upon Tyne, England. Two-week course on the treatment of trade wastes and the prevention of river pollution. Peter C. G. Isaac, Senior Lecturer, Public Health Engineering, Department of Civil Engineering, University of Durham, King's College, Newcastle upon Tyne, England.

INDUSTRIAL WASTES GUIDE—BY-PRODUCT COKE INDUSTRY *

By H. H. Black, G. N. McDermott, C. Henderson, W. A. Moore, and H. R. Pahren

Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio

This Guide supplements the earlier work published as a part of the Ohio River Pollution Control Report (1). Results are summarized herein for industrial waste surveys conducted by the U. S. Public Health Service at eight different by-product coke plants in the United States. Taste and odor studies, and bio-assays of coke plant wastes are included. Emphasis has been placed on definition of the problem, pollutional effects, remedial measures, and methodology.

Magnitude of Problem

In 1955 there were 82 by-product coke plants in the United States with some 15,000 ovens having an annual capacity of 78.6 million tons of coke. During the year 1954, there were 58 million tons of by-product coke produced, of which 52 million tons were used for blast furnace operations. Approximately 77 per cent of this coke was produced in the states of Pennsylvania, Ohio, Indiana, Alabama, New York, and West Virginia, with the relative rank of production being in the same order (2). Based on this level of operation, it can be conservatively estimated that 30 tons of phenol per day are produced in the untreated liquid wastes from by-product coke plants. Toxicity of these wastes is another major problem.

Description of Process

By-product coke is produced by heating bituminous coal in closed ovens out of contact with air and recovering the volatile products that are evolved. The ovens are constructed of silica brick and are arranged side by side in groups of 30 or more, each group being referred to as a battery. Modern ovens are about 40 ft. long, 10 to 14 ft. high, and 14 to 18 in. wide with a capacity of 10 to 22 tons of coal each. The ovens are heated by burning either coke oven or blast furnace gas in flues constructed in the oven walls.

The quality of the coke, and the quality and quantity of coal chemicals and gas are controlled by blending various types of high-volatile and low-volatile bituminous coals of the coking type. There is no precise formula but a typical blend would be 70 per cent high-volatile and 30 per cent low-volatile coal. Coal having a low ash and sulfur content is preferred. In general it is advantageous to charge a low-moisture coal, 4 to 5 per cent water, because of the saving in additional heat required to vaporize the water. Coal is charged through small openings in the top of the ovens by means of hopper-bottom cars that travel on tracks located on top of each battery. The coking period is normally 16 to 24 hr. with flue temperatures varying between 1,800° and 2,600° F., depending on the type of coke being produced. When carbonization is completed, the doors forming each end of the oven are removed and a pushing machine, equipped with a powerful ram, pushes the incandescent coke into the quench car. The quench car is quickly moved to a quench station

* Presented at 11th Industrial Waste Conference; Purdue University, Lafayette, Ind.; May 15–17, 1956.

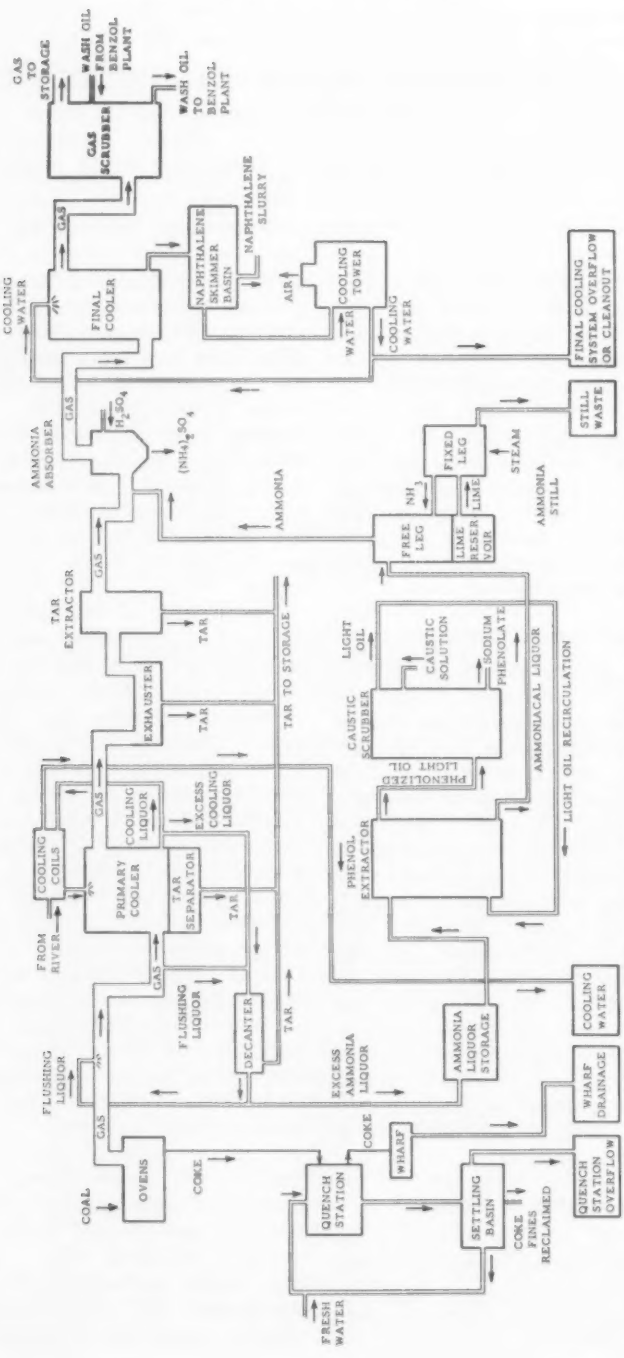

FIGURE 1.—Simplified flow diagram of a by-product coke plant showing liquid wastes sources.

where the coke is cooled by water sprays.

Volatile products of the coal leave the top of the ovens through standpipes which connect with a large gas collecting main extending the length of the battery. Initial cooling of the gases takes place in the collecting main where they are in contact with sprays of flushing liquor, which liquor has previously been condensed from the gases. This liquor is composed of the moisture in the coal and the water produced by decomposition of the coal. From the collecting main the gases then pass through primary coolers which may be either of the direct or the indirect type. The flushing liquor, carrying about 85 per cent of the tar, and the primary cooler condensate drain to one or more decanters for separation of the tar and liquor (Figure 1). Liquor condensed from the gases, referred to as ammoniacal liquor, is passed through an ammonia still for recovery of ammonia.

Pertinent data for raw ammoniacal liquor at seven coke plants are shown in Table I.

Ammonia Recovery Processes

Two processes are used in the United States for the recovery of ammonia from coke-oven gas. These are referred to as semidirect and indirect. Approximately 85 per cent of the ammonia produced in coke plants is recovered as ammonium sulfate by the semidirect process (3). The balance is produced as concentrated ammonia liquor by the indirect process. Recently some plants have started producing ammonium phosphate.

In the semidirect process, only a portion of the ammonia is dissolved in the ammoniacal liquor and the remainder stays in the gas. The volume of raw ammoniacal liquor produced by the semidirect ammonia recovery process varied between 17 and 28 gal. per ton of dry coal for the coke plants studied. The ammonia is distilled from the liquor and returned to the gas stream. The gas is then passed through an exhauster, a tar extractor, and a weak sulfuric acid bath (absorber) to produce ammonium sulfate. Pyridine bases are recovered from the mother liquor of the sulfuric acid ammonia absorber at some plants.

The indirect system substitutes a series of ammonia scrubbers for the sulfuric acid absorber. Ammonia is scrubbed from the gas by a countercurrent water wash. The ammonia concentration in the scrubber water is

TABLE I.—Raw Ammoniacal Liquor Characteristics and Volume Correlated with Design and Operations

Plant*	Phenols (lb.†)	Cyanide (CN) (lb.†)	Total NH_3 (N) (lb.†)	Flue Temp. (° F)	Volatile Matter (%)	Coal Moisture (%)	Volume (gal./ton dry coal)
Semidirect:							
A-1	300	—	—	2,300	29.8	—	17
A-2	130	7	890	2,470	30.5	5.7	18
A-3	160	—	—	2,400	31.3	6.3	19
B	250	3	490	2,325	35.4	4.5	21
C	80	6	470	2,500	25.7	4.9	18
D	250	6	1,080	2,550	29.0	4.4	21
E-2	280	26	2,400	2,020	28.0	4.5	28
Indirect:							
F-2	1,200	34	5,530	1,740	25.2	8	72
H-2	380	120	—	2,390	30.9	4.5	52

* Plants designated A-1, A-2, etc. are the same plant at which two or more surveys were made under different operating conditions.

† Pounds per 1,000 tons of dry coal.

increased by circulating it through one or more compartments of the direct-type primary cooler (4). The ammonia scrubber water and primary cooler condensate combine to give ammonia liquor. The volume of ammoniacal liquor produced by the indirect ammonia recovery system normally ranges between 60 and 90 gal. per ton of dry coal. The ammoniacal liquor is passed through an ammonia still to recover the ammonia as a concentrated ammonia liquor.

Light-Oil Recovery

Coke-oven gas contains approximately 1 per cent light-oil vapors by volume. Gas leaving the ammonia scrubbers of the indirect ammonia recovery system is at a suitable temperature for recovery of these light oils. However, gas leaving the ammonia absorber of the semidirect system is at a temperature of about 145° F. and must be cooled to 85° F. or lower for recovery of the light oil. This cooling is accomplished in a hurdle-packed tower (final cooler) by direct contact with water flowing countercurrent to the ascending gas. Practically every coke plant has a recirculation system for this final-cooler water, employing either a cooling tower or a spray pond. Evaporation loss normally exceeds the quantity of water condensed from the gas. Cooling coils may be used in lieu of cooling towers, when their operation might cause objectionable air pollution, in which case the condensate is sewered. Naphthalene is condensed from the cooled gas in the form of crystals and is continuously removed from the gas final-cooler water.

Light oil is scrubbed from the cooled gas by a high-boiling wash oil. The light oil is then distilled from the wash oil and the wash oil is cooled and recirculated. This light oil is refined by stills and fractionating columns (Figure 2). Benzene, toluene, and the xylenes are the principal constituents of light oil, although there are a large number of other compounds present in small amounts.

Coke Quenching

The incandescent coke must be promptly cooled by water sprays to prevent combustion. This quenching operation is automatically controlled and requires 1 to 2 min. The time is adjusted so that most of the fire is extinguished but sufficient heat is retained in the mass of coke to evaporate most of the entrained water.

Raw Materials and Products

The yields and characteristics of the carbonization products depend primarily on the amount of volatile matter in the coal and the severity, duration, and nature of the heat treatment. Other variables believed significant but not fully evaluated are:

1. The type and preparation of the coal.
2. Oven design and charging practice.

Carbonization of coal results in relatively few major products. However, from these products, some of which are available economically from no other source, stem hundreds of other chemicals and literally thousands of products.

The normal ranges for raw materials and products, per ton of dry coal carbonized, are as follows:

Raw Material	Quantity (lb./ton)
Sulfuric acid, 66° Be.	17–27
Sodium hydroxide	0.2–0.5
Lime	1.0–1.8

Principal Products	Quantity (units/ton)
Coke (lb.)	1,300–1,550
Gas (cu. ft.)	10,000–12,500
Tar (crude) (gal.)	5–12
Ammonia (NH_3) (lb.)	4–7
Light oil (crude) (gal.)	2–4
Pyridine (crude) (gal.)	0.014
Naphthalene* (lb.)	1.6

* From final coolers and benzol plant.

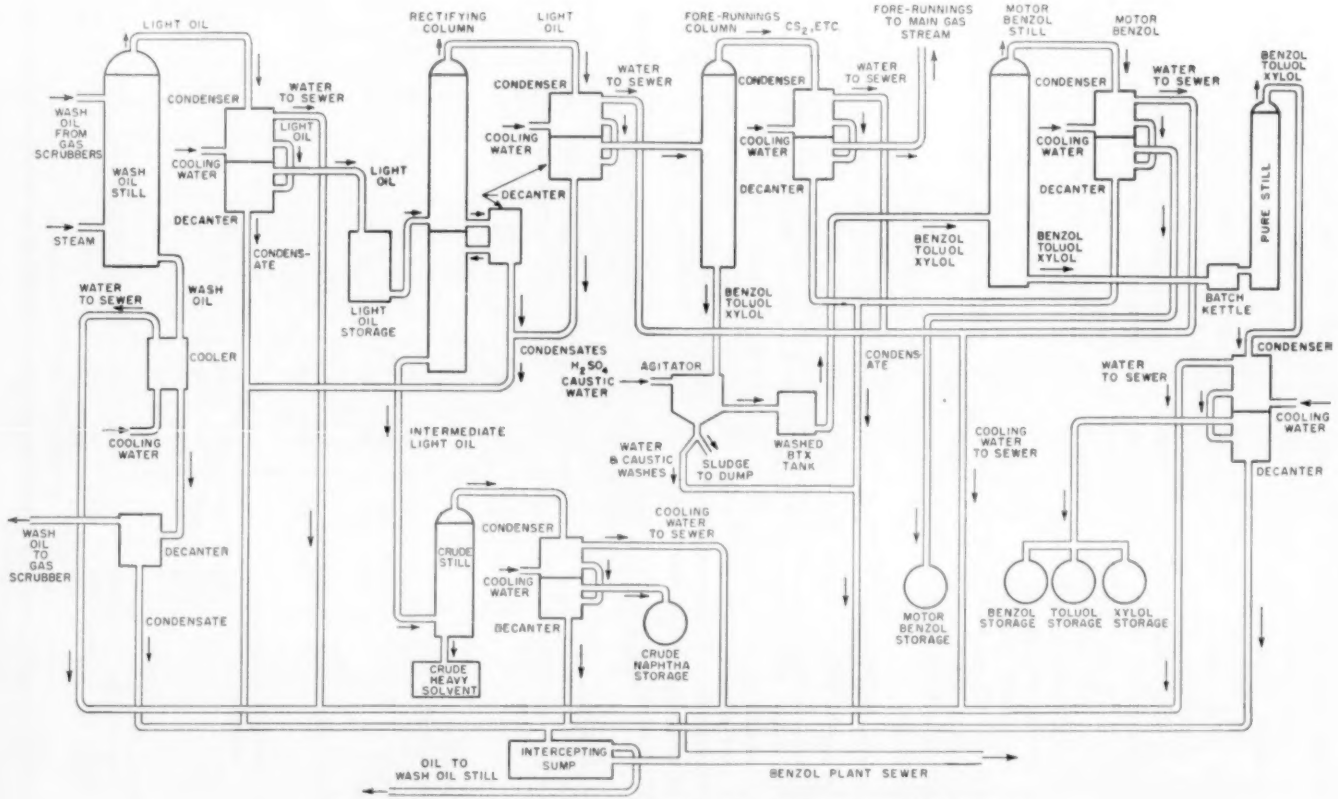

FIGURE 2.—Simplified flow diagram of light-oil recovery and refinery.

Volume and Character of Wastes

The most important liquid wastes discharged from a by-product coke plant are ammonia still waste and benzol plant wastes. The latter are more accurately referred to as light-oil recovery and light-oil refining wastes. Gas final-cooler water is usually recirculated but any overflow constitutes a highly pollutional waste. Quench water and cooling water add materially to the volume but ordinarily do not contribute significant pollution. There are always some residual wastes originating from equipment maintenance, inevitable leaks, and process irregularities.

Ammonia Still Waste

Ammonia still waste is the liquor resulting from steam stripping ammonia from raw ammoniacal liquor. The volume of still waste is 20 to 40 per cent greater than the volume of raw liquor feed, because of condensate from steam applied directly to the still and milk of lime added to decompose fixed ammonia. The volume of ammonia still waste per ton of coal carbonized varies significantly at different plants as indicated in Table II. The influencing factors are:

1. Ammonia recovery process.
2. Moisture of coal, usually 4 to 6 per cent.
3. Water produced by decomposition of coal.
4. Steam used in the still (wet or dry).
5. Milk of lime used in the ammonia still.

The composition of ammonia still wastes is related directly to the volatility of the coal carbonized, to coking temperature, and to design and operation of the various units. Comparison of the phenol content in the raw ammoniacal liquor for Plants C and D, Table I, gives a striking example of the influence of volatile matter on the liquor. Likewise in Table II, the coal

TABLE II.—Ammonia Still Wastes Characteristics and Volumes Correlated with Design and Operations

Plant*	Characteristics (lb./1,000 tons of dry coal)							Vol. (gal./ton of dry coal)	Flue Temp. (°F.)
	Phenols	Cyanide (CN)	Thiocyanate (SCN)	Total NH_3 (N)	Sulfides (H_2S)	Chloride (Cl)	B.O.D., 5-day		
Semidirect:									
Vapor recirc.:									
A-1	46	0.4	—	7.1	69	—	150	20	2,300
A-2	7.3	4.5	57	5.7	—	—	—	21	2,470
B	48	0.9	230	28	—	420	280	27	2,325
Benzol extraction:									
C	7.4	2.9	66	14	4	—	—	23	2,500
No recirc. or extract. process:									
D	230	1.0	—	80	8	1,800	470	33	2,550
E-1	72	0.4	—	870	—	—	370	20	2,250
E-3	120	5.2	240	—	—	—	—	24	2,200
Indirect:									
G	640	2	—	52	33	1,700	1,200	110	2,460
H-1	475	2.4	—	55	32	—	1,400	60	2,390
H-2	320	6.3	500	—	—	—	—	68	2,390

* Plants designated A-1, A-2, etc. are the same plant at which two or more surveys were made under different operating conditions.

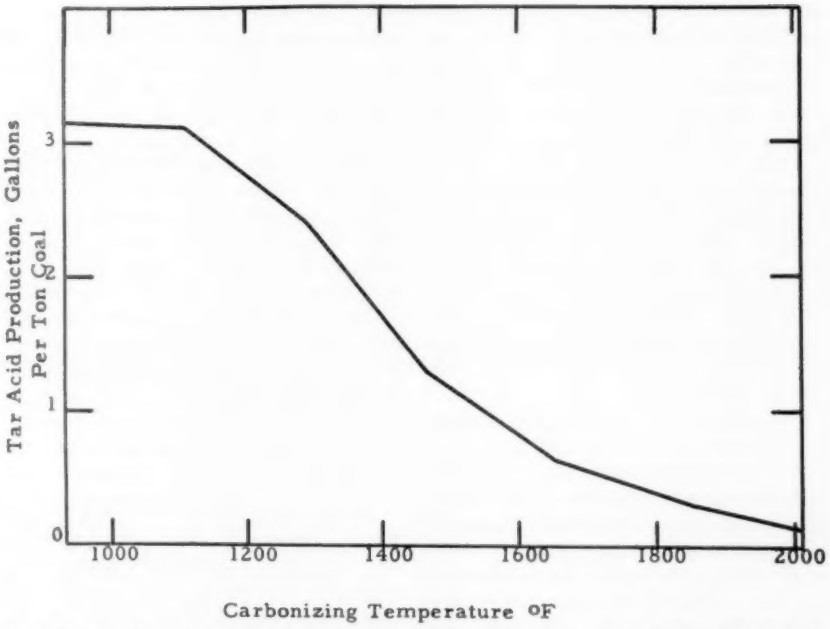

FIGURE 3.—Tar acid production at different coking temperatures (Pratt unwashed coal).

volatility for H-1 was 34.9 per cent and for H-2 it was 30.9 per cent. Tar production at Plant C was the lowest for the coke plants studied. This low tar yield was associated with the lowest phenols observed in the ammoniacal liquor (Table I).

The U. S. Bureau of Mines has demonstrated that the production of tar and the per cent of tar acids in

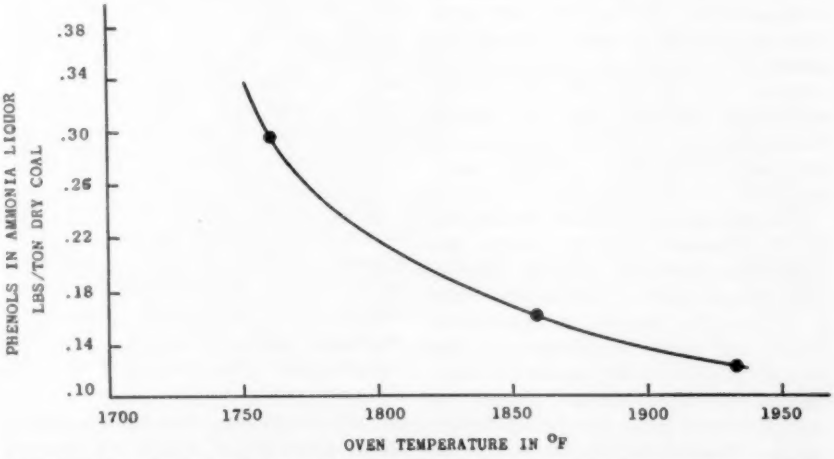

FIGURE 4.—Variation of phenol in ammoniacal liquor at different oven temperatures, Plant A.

the tar both decrease progressively with increasing temperature of carbonization (5). The effect of coking temperatures on production of tar acids (phenols) is illustrated by Figure 3. In like manner, the phenol content of ammoniacal liquor varies directly with the coking temperature (Figure 4). This curve shows variations in phenol in the ammoniacal liquor for the same coke plant operating at different coking temperatures. These data indicate that within a relatively narrow temperature range, phenol production may vary as much as 200 to 300 per cent.

Comparison of phenol unit values for the indirect and the semidirect ammonia recovery plants (Tables I and II) affords an excellent illustration of the influence which the volume of ammoniacal liquor has on the amount of phenolic constituents dissolved from the tar. This is an example of the distribution of a solute between two immiscible solvents. Phenol in the ammoniacal liquor for Plant H was significantly lower than the other indirect ammonia recovery plants. This was attributed to the fact that a separate tar decanter was provided for the flushing liquor. The primary cooler condensate and the ammonia scrubber water at Plant H were combined and passed through a second decanter. Provision of a separate tar decanter for flushing liquor at the semidirect ammonia recovery plants should likewise reduce to a minimum the takeup of tar acids (phenols) from the tar.

The ammoniacal liquor of the indirect ammonia recovery plants absorbs more hydrogen cyanide (HCN) from the gas than it does in the semidirect process, because of the larger volume and lower temperature in the former process. The ammonia still effluent was the principal source of cyanide waste from the indirect-type plants. Some HCN distills over with the ammonia into the ammonia water concentrate. There is a strong tendency for thiocyanates to form in the ammoniacal liquor from HCN in the presence of sulfides and free ammonia. Thiocyanates as high as 2,000 p.p.m. have been reported in the ammonia still waste.

Most of the ammonia in raw ammoniacal liquor is present as either "free" or "fixed" ammonium salts. Free salts are readily decomposed by boiling whereas the fixed salts must be boiled with an alkali. The effluent from a properly operated ammonia still should contain not more than 500 p.p.m. ammonia and normally this will be less than 300 p.p.m.

Light-Oil Recovery and Refinery Wastes

Benzol plant operations vary in different plants but the basic processes are similar. Condensed steam from stripping operations and cooling waters constitute the bulk of the liquids going to the sewers. There is little, if any, carryover of moisture from the gas scrubbers to the benzol plant. The volumes of liquid wastes discharged from benzol plants vary considerably depending on whether or not cooling water is recycled or discharged directly to the sewer. Flow data obtained at five plants, which included cooling water, showed values from 375 to 750 gal. per ton of dry coal. At three other plants, where the cooling water was either recycled or discharged to a different sewer, the benzol plant discharge varied from 20 to 89 gal. per ton of dry coal.

When water comes in direct contact with the process stream, a certain amount of soluble material is absorbed by the water. The overhead from each distilling column usually goes to a condenser and a decanter. The discharges from these decanters and the agitator wastes are the chief sources of pollutants in the benzol plant. Minor quantities of wastes are released from wash-oil cleaning operations and storage tank drains. Some benzol

TABLE III.—Benzol Plant Effluent Correlated with Design and Operations

Ammonia Recovery Process	Semidirect						Indirect	
Gas Final-Cooler System	Cooling Tower and Recirculation (closed system)					No Tower†	None	
Dephenolization System	Vapor Recirculation		Benzol Extraction		None			
Plant*	A-2	B	A-3	C	D	E-2	H-1	H-2
Phenols (lb.‡)	11	56	29	6	7	0.09	1	0.5
Cyanide (CN) (lb.‡)	3.1	8.7	—	1.9	1.5	0.02	—	5.0
Total NH_3 (N) (lb.‡)	9.4	12	—	—	1.2	0.05	5.0	14
Phenol§ (p.p.m.)	850	1,410	1,020	550	1,480	1,210	—	880

* Plants designated A-2, A-3, etc. are the same plant at which two or more surveys were made under different operating conditions.

† Cooling water discharged directly to a sewer.

‡ Pounds per 1,000 tons of dry coal. § Ammoniacal liquor.

plants discharge residue removal column tailings to the sewers.

Table III presents data on the effects of the type of operation on benzol plant wastes. The concentration of phenol in a scrubbing water is one of the factors that determines the amount of phenol that it will absorb. Thus, the vapor pressure of phenol in fresh water would be zero, and this water would tend to absorb more phenol from a gas stream than recirculated water which already contained phenol. The indirect ammonia recovery system scrubs the gas stream with fresh water and, in addition to removing almost all of the ammonia from the gas, the scrubber water is effective in absorbing phenol. A similar situation existed in Plant E in the once-through final cooler. The carryover of phenol in the gas to the benzol department, in the semidirect ammonia recovery systems, is clearly illustrated in Table III.

The debenzolized wash oil from the still is cooled and any contained water is separated before returning the oil to the scrubber. The water may be decanted before and/or after the coolers. In addition to light oil, wash oil absorbs tarry particles, complex unsaturated organic compounds, hydrogen sulfide, phenols, and other sulfur compounds. These compounds react with each other to produce gummy or tarry materials which form a muck. This muck inhibits light-oil recovery and must be removed intermittently from decanters or continuously in steam-heated wash-oil purifiers. The muck is boiled with steam to break emulsions. The good oil is then separated by decantation, and the water and residue are discarded to the wastes sewer.

The characteristics of decanter discharge depend largely on the volumes of steam used and the nature of the process material. The amounts of materials dissolved in the water again depend on relative solubilities. Partial analysis of three decanter effluents at one plant, employing a rectifying column after the stripping still, are given in Table IV.

Light oil is treated with sulfuric acid in a lead-lined agitating tank to remove sulfur-containing and unsaturated organic compounds. The consumption of 66° Be. acid usually ranges between 0.4 and 0.8 lb. per gallon of light oil washed. The acid is added in two or more washes. The reactions between the sulfuric acid and the organic compounds are complex and the gummy materials formed are removed in the form of sludge. It is common practice to wash the acid-treated light oil with water (approxi-

TABLE IV.—Concentrations of Waste Constituents in Decanter Effluents at One Light-Oil Recovery and Refining Plant

Waste Constituent	Primary Decanter* (p.p.m.)	Intermediate Decanter† (p.p.m.)	Secondary Decanter‡ (p.p.m.)
Phenols	420	240	29
Cyanide (CN)	4.5	7.8	240
Sulfides (H_2S)	1.4	5.3	150
Thiocyanate (SCN)	24	3.1	4.0
B.O.D., 5-Day	1,040	870	360
pH	6.9–7.3	7.7–7.9	6.5–6.6

* After wash-oil still condenser.

† On line of heavy fraction of light oil between bottom and top of rectifying column.

‡ On overhead line of rectifying column, after condenser and prior to fore-runnings column.

mately 0.1 gal. of water for each gallon of light oil) before neutralizing with alkali.

It is customary to dispose of the spent acid and sludge on dumps or occasionally by burning. Recovery and re-use of the acid is possible but not economical. With few exceptions, rinse water and spent caustic are discharged to the sewers through the intercepting sump.

Gas Final-Cooler Water

Gas final-cooler water constitutes a serious pollution threat at all by-product coke plants. This cooling water comes in direct contact with the gas from the ovens and is a potential source of highly toxic cyanogen compounds in coke plant effluents. Hydrogen cyanide is the principal cyanogen compound in the coal gas. High temperature carbonization produces considerably more cyanide than low temperature coking. This is shown in Table V for studies E-1 and E-2. It is formed in coke ovens by the reaction of ammonia with carbon or such carbon compounds as acetylene.

Hydrocyanic acid is an extremely water soluble compound and accordingly may be expected in water condensed from the gas and in other water that has been in contact with the gas. Its low boiling point (26° C.) and correspondingly high vapor pressure result in relatively rapid volatilization from dilute aqueous solutions, at a normal pH range, when agitated and exposed to the atmosphere.

Cooling of coke-oven gas in the final cooler condenses about 5 gal. of water from the gas per ton of dry coal carbonized. Plants employing closed systems, and adiabatic evaporation in a cooling tower, use 250 to 500 gal. of water in the final cooler per ton of coal. Cooling of the gas is largely dependent on the temperature of the cooling water which in turn is a func-

TABLE V.—Gas Final-Cooler Water Concentrations of Pollutional Constituents for Three Types of Cooling Systems

Item	System*					
	Cooling Tower and Recirculation (closed system)			Cooling Water Direct to Sewer		Cooling Coils, Condensate to Sewer
	B	C	D†	E-1	E-2	E-3
Phenols (p.p.m.)	1,140	250	1,700	5	3.8	380
Cyanide (CN) (p.p.m.)	140	220	270	160	26	200
Sulfides (H_2S) (p.p.m.)	16	3	1,125	10	—	—
Thiocyanate (SCN) (p.p.m.)	140	290	3,340	—	—	730
B.O.D., 5-Day (p.p.m.)	2,890	—	—	495	425	—
Flue temp. (°F.)	2,325	2,500	2,550	2,250	2,020	2,200
Flow to sewer (gal. per ton dry coal)	0	0	0	1,400	2,420	5.8

* Plants designated E-1, E-2, etc. are the same plant at which two or more surveys were made under different operating conditions.

† Soda ash added to reduce sulfide concentration of gas sold for domestic use.

tion of atmospheric temperature, relative humidity, and the capacity of the water cooling system. It is not uncommon to find these water cooling systems over-loaded in the summer or during peak production. Introduction of cool water into the recirculating system during such periods may cause overflow or additional discharge of these highly pollutional wastes.

Water soluble substances are absorbed in the final-cooler water and build up in concentration as the water is recirculated. This is especially true if alkaline chemicals are added as was the case at Plant D. Sulfides are normally driven off in the cooling tower or they are converted to thiosulfates and thiocyanates. Cyanogen compounds build up to a moderate degree but most of the cyanide escapes in the cooling tower. The amounts of waste constituents removed from the gas decrease as their concentrations increase in the recirculated final-cooler water. This is reflected in the benzol plant effluent for Plants E-1, H-1, and H-2 where phenols and cyanide were efficiently scrubbed from the gas in the once-through final cooler and by the ammonia scrubbers of the indirect system.

Cooling Water

Indirect cooling water is not normally considered waste but leaks in coils or tubes may be a significant source of pollutional materials. This applies to any cooling system in which the process stream is under greater pressure than the cooling water. Leakage of ammoniacal liquor through these coils at one plant amounted to 6 g.p.m. This represented 60 lb. phenols per day as well as considerable ammonia.

Coke Quench Wastes

Quenching of coke requires some 500 gal. of water per ton of coke. Roughly 30 per cent of this water is evaporated by the hot coke and is carried into the air as steam emanating from the quench tower. Hot water, draining from the coke, flows to a settling basin for removal of coke fines. The settled water either overflows to the sewer or is recirculated. When fresh water is used for quenching, traces of pollutional materials are picked up from the coke but an increase in temperature is the principal objectionable feature of the settled waste.

Miscellaneous Wastes

The volume and character of miscellaneous wastes are a function of equipment design and maintenance, and of operation. Provision is usually made for the salvage of materials when equipment and process pipe lines must be drained. Nevertheless there are numerous losses to the sewers which are associated with operation. Equipment maintenance and good housekeeping are both major factors affecting such losses.

Coke Plant Total Wastes

Effluent data for eight different by-product coke plants are given in Table VI. Interpretation of these results requires background information which has been given in the preceding tables and accompanying discussion. The most striking results are for Plant B where benzol plant wastes and dephenolized ammonia still wastes were used for quenching coke. Cooling water was recirculated and the only discharge from Plant B was intermittent overflow from the quench system caused by inadequate storage.

Pollutional Effects

The taste and odor producing properties of by-product coke wastes are of foremost concern. These wastes contain significant quantities of chemicals known to be toxic to aquatic life, and they exert a considerable oxygen demand on receiving waters. Elevation of stream temperature by the warm discharge inhibits aquatic life and limits immediate re-use of the stream for cooling purposes.

TABLE VI.—Concentrations and Quantities of Pollutional Constituents in By-Product Coke Plant Wastes

Ammonia Recovery Process	Semidirect			Indirect					
Dephenolization System	Vapor Recirculation		Benzol Extraction	None					
Plant	A-2	B	C	D	E-1	F-2	G	H-1	H-2
Phenols (p.p.m.)	1.9	280	1.9	25	11	34	29	17	11
Cyanide (CN) (p.p.m.)	0.35	6.0	0.66	0.54	155	0.15	1.7	0.14	0.20
Total NH_3 (N) (p.p.m.)	2.5	25	1.5	7.4	78	1.5	8.4	2.3	—
Thiocyanate (SCN) (p.p.m.)	—	73	9.3	—	—	12	—	—	16
B.O.D., 5-Day (p.p.m.)	—	990	—	94	520	—	63	63	—
Phenols (lb.)*	48	9	14	340	132	1,170	660	480	330
Cyanide (CN) (lb.)*	8.7	0.2	5	7.5	1,850	5	39	4	6
Total NH_3 (N) (lb.)*	62	1	10	100	920	50	90	65	—
Thiocyanate (SCN) (lb.)*	—	2	67	—	—	420	—	—	490
B.O.D., 5-Day (lb.)*	—	32	—	1,300	6,150	—	1,320	1,800	—
Volume (gal. per ton of dry coal)	2,960	4	860	1,650	1,420	4,100	2,740	3,450	3,670

* Pounds per 1,000 tons of dry coal.

Taste and Odor

The phenolic constituents of by-product coke wastes have long been associated with taste and odor in drinking water. Phenol itself is not taste producing in low concentrations. However, its importance as a taste problem stems from the fact that chlorination increases the taste intensity. It has been demonstrated in the laboratory that the intensity of the taste of pure phenol in water is increased 500 to 1,000 times by chlorination. The maximum taste intensity is developed at certain ratios of chlorine to phenol.

Oxidation methods, such as breakpoint chlorination or chlorine dioxide treatment, and adsorption on activated carbon are effective in reducing taste intensity but they are expensive. The chlorophenol taste is commonly described as "medicinal" and is particularly unsavory. People with average taste sensitivity can detect chlorophenol in water in concentrations of 1 to 2 p.p.b. Both the 4-aminoantipyrine and the Gibbs Methods determine not only phenol but also cresol and a variety of phenolic compounds, most of which are similar to phenol in taste and odor producing properties.

Less is known about the taste and odor potential of the constituents other than phenol in by-product coke wastes. The USPHS has done some preliminary work on ammonia still waste, from a plant using the Koppers vapor dephenolization system, by extraction with diethyl ether and separation of strongly acidic, weakly acidic, neutral, and basic compounds. These observations indicated that the weak acid fraction, which contained the preponderance of residual phenolic materials, was somewhat overshadowed in its contribution of odor by the strong acids, neutrals, and bases. Although chlorination reverses this relation, it appears that nonphenolic materials have some significance in the residual wastes from by-product coke plants. It further appears that when other organic materials are present in water the multifold increase in odor intensity exhibited by pure phenol, following chlorination, is of lesser magnitude. The results of these studies strongly suggest the need for evaluating both phenolic and non-phenolic constituents in coke plant wastes to accurately estimate their taste and odor producing potential.

Toxicity of Components to Aquatic Life

By-product coke wastes contain numerous chemical compounds which are

known to be toxic to aquatic life in low concentrations. These include cyanide, sulfides, ammonia, and phenols. Other highly toxic materials which may be present in significant concentrations are toluene, benzene, acridine, quinoline, and naphthalene. Process wastes that have been in contact with coal tar and the light oils may be expected to carry traces of a great variety of compounds. Information is available and summaries have been published indicating the toxic effects of many of these compounds on fish (6) (7) (8) (9).

Hydrocyanic acid (HCN) and its salts are among the most violent poisons known. The most potent source of HCN in coke plant wastes is the gas final-cooler water (Table V). This is reflected by the data for Plant E, Table VI. Plant E used the once-through gas final-cooler system and discharged a considerable quantity of cyanide.

The toxicity of cyanides is affected by the proportion of cyanide ion to the undissociated molecule. Hydrocyanic acid is more toxic than the equivalent concentration of hydrogen and cyanide ions. Hydrocyanic acid forms in water when either NaCN or KCN is added. The HCN dissociates into hydrogen and cyanide ions according to the reversible reaction.

$$HCN \leftrightarrows H^+ + CN^-$$

The dissociation constant for HCN is 7.2×10^{-10} at 25° C. Therefore, the ratio of cyanide ion to HCN is a function of pH as follows:

$$\frac{[CN^-]}{[HCN]} = \frac{7.2 \times 10^{-10}}{[H^+]}$$

It is evident that cyanide becomes more toxic at the lower pH values.

Available information indicates that cyanide (CN) should not exceed 0.05 p.p.m. in receiving waters. Under certain conditions, somewhat lower values may have a detrimental effect on aquatic life.

Hydrogen sulfide in concentrations of 1 to 6 p.p.m. has been reported lethal to different kinds of fish under variable water quality conditions. Other sulfides such as sodium sulfide are hydrolyzed in solution yielding hydrogen sulfide. The pronounced toxicity of solutions of sulfides may be attributed to the release of hydrogen sulfide as the pH is lowered. For the protection of aquatic life, hydrogen sulfide in receiving waters should not exceed 0.5 p.p.m.

The toxicity of ammonia and ammonium salts to fish is directly related to the amount of undissociated ammonium hydroxide in solution, which in turn is a function of pH. Ellis (7) has reported that the toxicity to fish of a given concentration of ammonium compounds increased 200 per cent or more when the pH was raised from 7.4 to 8.0. Available data indicate that ammonia in excess of 2.0 p.p.m., in the pH range of most natural waters, may be expected to affect aquatic life. Concentrations greater than 2.0 p.p.m. may be non-toxic and lesser concentrations can be toxic, depending on the characteristics of the receiving stream.

Phenols in excess of 5 p.p.m. may be expected to be toxic while concentrations of 1 p.p.m. or less will probably be safe; however, some chlorophenols are toxic below this level. Sub-lethal concentrations of various phenolic compounds impart an offensive taste to fish flesh.

Following are concentrations reported lethal to fish for certain materials likely to be present in coke plant wastes (6) (7) (10):

Constituent	Quantity (p.p.m.)
Cresylic acid	0.1
Acridine	0.7
Naphthalene	4–10
Naphthenic acid and naphthene derivatives	3–20
Quinoline	7.5
Benzene	20
Toluene and xylene	22–90

These results represent short time exposure of various types of fish. The

concentrations would have to be reduced substantially to permit normal aquatic life in a stream.

Ferro- and ferri-cyanides are normally non-toxic when the concentration is less than 2,000 p.p.m. However, in bright sunlight, 2 p.p.m. of these compounds may be toxic because of photodecomposition and release of the cyanide ion (11). Similarly, thiocyanates, which are usually non-toxic at concentrations of less than 150 p.p.m., may become toxic at concentrations as low as 6 p.p.m., when chlorinated to a slight residual as a result of the release of cyanide or the formation of cyanogen chloride.

Bio-Assay Studies

The foregoing information on toxicity must be used with caution because biological data are not adaptable to rigid application. In some wastes one toxic constituent may predominate while in others toxicity may result from the combined effect of several components. The same wastes in admixture or under the influence of non-toxic constituents may exert an entirely different degree of toxicity from the separate compounds. Bio-assays are extremely helpful in estimating the toxic effect on fish of complex industrial wastes.

The bio-assay procedure used on coke plant wastes consisted of preparing several concentrations of the waste, using water from the receiving stream for dilution, adding test fish, and observing their reaction over a definite time period (12). Test fish were fathead minnows, *Pimephales promelas*. Toxicities were expressed as median tolerance limits (TLm), which were the concentrations of the wastes in dilution water which killed one-half of the fish in 48 hr.

Bio-assays of five, 8-hr. composite samples of the final effluent from one by-product coke plant gave 48-hr. TLm values ranging from 4 to 14 per cent, with an average of 7.5 per cent. Typical analysis of the dilution water showed 95 p.p.m. total alkalinity, 125 p.p.m. versenate hardness, and a pH of 8.2.

TABLE VII.—Bio-Assay Results on Some Toxic Constituents in By-Product Coke Wastes

(*a*) Pure Compounds

Compound Tested	48-Hr. TLm Conc. (p.p.m.)
Sodium cyanide (NaCN)	0.24 (CN)
Ammonium hydroxide (NH_4OH)	7 (N)
Phenol (C_6H_5OH)	40
O-Cresol ($CH_3C_6H_4OH$)	24
Sodium sulfide ($Na_2S \cdot 9H_2O$)	1.38 (H_2S)

(*b*) Chemicals in Final Effluent

Constituent	Range of Concentration (p.p.m.)
Cyanides (CN)	0.02–0.30
Free ammonia (N)	5.8–11
Phenols	37–48
Sulfides (H_2S)	0.51–1.15

In an effort to evaluate the toxic effect of some of the known components in these wastes, bio-assays were run on pure compounds under the same test conditions. The results (Table VII) show that these compounds account for only a small part of the toxicity in the final effluent. It is evident that other unknown materials of a highly toxic nature were present or that there was a strongly synergistic action between some known components.

Concentrated wastes inside the plant were examined by bio-assays for significant sources of toxic materials. This work gave the following data:

Waste Source	48-Hr. TLm (%)
BTX caustic wash	0.005
Ammonia still waste	1.25
Light-oil decanter discharge	2.5
Gas final-cooler recirculating water*	0.7

* Normally no overflow to sewer.

Bio-assays of ammonia still wastes from a coke plant that dephenolized the ammoniacal liquor by solvent extraction gave a 48-hr. TLm of 7.5 per cent. This indicates considerable reduction in toxicity. Phenols are not considered a major producer of toxicity in coke plant effluents; however, it is possible that other toxic materials are removed by dephenolization.

Again, care must be exercised in the application of bio-assay data. The concentrations expressed as TLm values will kill 50 per cent of a fairly hardy test fish in a short time period. Obviously these concentrations would not be considered safe for aquatic life. Liberal factors must be used in applying the results. A completely safe concentration may be as low as one-tenth of the 48-hr. TLm value. These studies demonstrated the value of bio-assays in tracing sources of toxic components of wastes within a plant and served to emphasize the highly toxic nature of by-product coke effluents.

Dissolved Oxygen Depression

Coke plant effluents have a significant B.O.D. and may damage fish by oxygen depression. Some chemicals, especially those which affect the gills, are much more toxic under low oxygen conditions. Sufficient oxygen must be available to support normal life processes such as obtaining food, swimming against currents, and reproduction. Temperature, carbon dioxide, and stream velocity affect the oxygen requirements of fish. The dissolved oxygen concentration should be 5.0 p.p.m. or higher to maintain a desirable mixed warm-water fish population.

Temperature Increase

The elevation of stream temperatures by discharge of coke plant wastes may have a serious effect on aquatic life. The toxicity of many chemicals to fish is increased by raising the water temperature. Likewise the metabolic rate and oxygen requirements of fish increase with temperature rise. Fish food organisms may also be affected. Most fish have definite temperature limits between which they will spawn. Water temperatures of 95° F. for most species of warm-water fishes and 83° F. for trout approach lethal levels. Maximum temperatures of extended duration should be considerably lower than these and abrupt changes of even a few degrees should be prevented if aquatic life is to be protected.

Remedial Measures

Remedial measures should be directed toward prevention of tastes and odors in public water supplies and protection of aquatic life. In the past, emphasis has been placed on phenolic compounds because of their effect on drinking water. However, efficient removal of phenols from coke plant wastes does not solve the toxicity problem. Though interrelated, tastes and odors, and toxicity are two distinct problems. This discussion is confined to generally accepted recovery and treatment methods. An excellent literature review and bibliography covering recovery and treatment methods for by-product coke wastes has recently been published by Hodge (13).

Dephenolization of Ammoniacal Liquor

Recovery of phenols from ammoniacal liquor, though not economically sound, offsets the cost of pollution abatement. The economics are strongly in favor of synthetic processes which account for some 95 per cent of the phenol produced in the United States (14). Two processes are in common use for dephenolization, namely: solvent-extraction and Koppers vapor-recirculation.

Benzol or light-oil extraction has been used extensively in Germany and in recent years has gained favor in the United States. In this process the ammoniacal liquor is in intimate con-

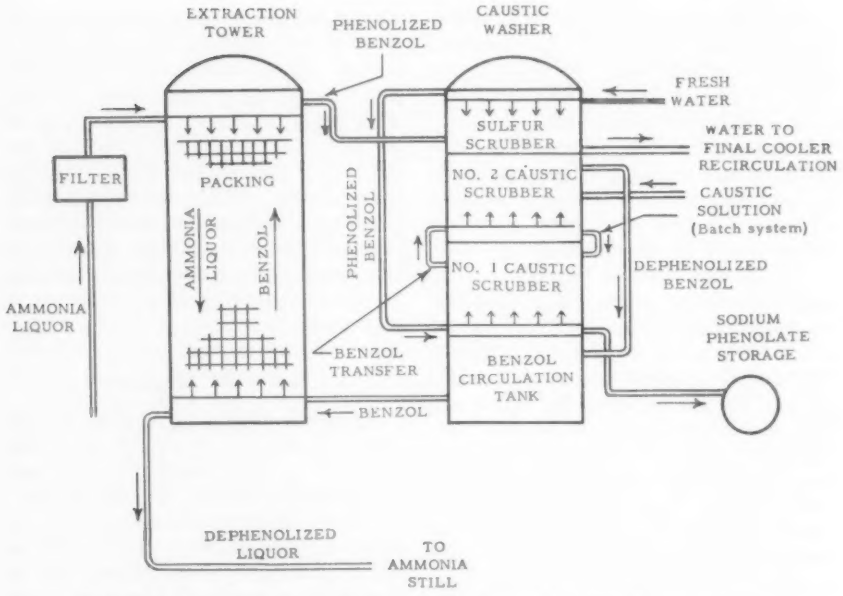

FIGURE 5.—General flow diagram of the benzol dephenolization process.

tact with benzene in a countercurrent extraction system prior to entering the ammonia still. This is a desirable feature from the standpoint of wastes inasmuch as the maximum amount of phenols are removed promptly.

A general flow diagram of the benzol countercurrent type of dephenolization process is shown in Figure 5. Filtration of the liquor through porous stone removes tar and suspended material. The two contact towers are packed with screened coke, wooden hurdles, or spiral tile. The benzol flows upward, absorbing phenols from the descending ammoniacal liquor, and overflows at the top of the extraction tower. The dephenolized liquor flows to the ammonia still. Phenol bearing benzol flows through a two-stage, packed contact tower containing a solution of 20 to 30 per cent caustic soda to produce sodium phenolate. The sulfur scrubber shown in Figure 5 is used in some plants. The benzol recycles through both towers acting as a carrier medium for the phenols. Sodium phenolate is salable or it may be converted to phenol by acid treatment.

The principal factors affecting the efficiency of benzol extraction are temperature, solvent-liquor ratio, and the intimacy of contact between the two liquids. The efficiency declines with a decrease in the benzol-liquor ratio. A recently constructed plant consistently gave 98 to 99 per cent phenol removal using 1.5 gal. of solvent per gallon of liquor (15).

One of the major causes of decreased efficiency is the formation of emulsions which results in blockage of packing and lines. Emulsions are attributed to absorption of tar in the circulating benzol. This can be alleviated by continuous withdrawal of fouled solvent and replacement with fresh light oil. The portion withdrawn is distilled to recover the benzol.

German dephenolization practice emphasizes pretreatment (16). The liquor is first filtered through sand and then passed through a column filled with benzol. This benzol is soon

saturated with phenol after which it continues to absorb organic material and neutral oils for a period of 3 to 10 days. Benzol employed in pretreatment is suitable, after distillation, for use in the principal extraction. Advantages claimed for this system are an elimination of emulsions, a reduction in the quantity of benzol required, and a minimum loss of solvent. This preliminary treatment permits solvent-liquor ratios as low as 1 to 1 and gives phenol removal efficiencies in the low nineties.

Recent developments in liquid-liquid extraction, applicable to dephenolization of ammoniacal liquor, include the Podbielniak centrifugal extractor and the Shell Development Company rotating disk contactor. Both devices provide maximum intimacy of contact between the two liquids and give high efficiencies.

In the vapor-recirculation process (Figure 6), liquor from the base of the free leg of the ammonia still is sprayed into the top of the tower. The liquor flows down over wooden-hurdle packing, countercurrent to a large volume of low pressure steam. Due to the vapor pressure of the phenol, it passes into the steam. The dephenolized liquor flows by gravity to the fixed leg of the ammonia still. The blower draws the phenol-laden steam from the top of the tower and discharges it into the lower or caustic section where it is scrubbed with caustic. The phenol-free steam enters the dephenolization section to complete the cycle, and the phenol is recovered as sodium phenolate.

Feed to the vapor recirculation system is taken from the base of the free leg of the ammonia still to avoid the acidic gases, carbon dioxide, hydrogen sulfide, and hydrogen cyanide which would react with the caustic. Free ammonia and a considerable amount of phenol are stripped from the am-

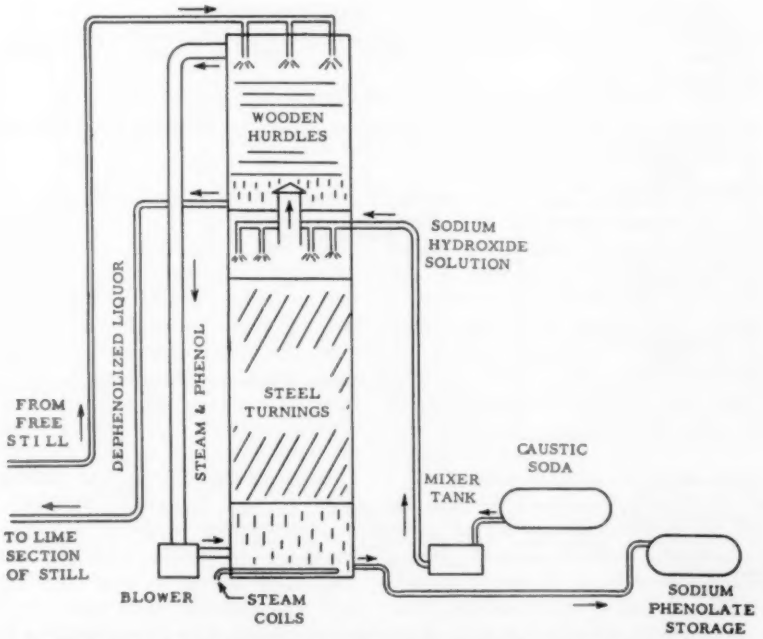

FIGURE 6.—Flow diagram of the Koppers vapor dephenolization system.

moniacal liquor along with these gases in the free leg of the still. This phenol, which carries into the gas stream, builds up in the gas final-cooler water and some phenol appears in the benzol plant wastes as shown for Plant B in Tables III and V.

Performance tests run on four plants gave the following results based on feed to and discharge from each dephenolization unit:

Dephenolization Process	Plant	Phenol Removal (%)
Benzol extraction	A-3	98.4
	C	90.9
Vapor recirculation	A-2	87.1
	B	70.2

Consumption of Wastes by Coke Quenching

Disposal of ammonia still wastes by coke quenching is practiced at a large number of coke plants in the United States. This method of disposal is certainly the most effective and complete because it not only controls phenols but also all other pollutional constituents. This may be especially important in view of the taste and odor potential, and the toxic effects of these wastes. Figure 7 shows a coke quenching system for disposal of all liquid wastes from a by-product coke plant.

A completely closed system is necessary with provision for recirculating the water which drains from the coke. This system retains all coke breeze and removes the high-temperature discharge from the sewers. Sufficient storage should be provided in the quench-water system to store wastes for certain periods such as shift changes when the pushing of coke from the ovens is temporarily suspended. The addition of fresh water to the system should be controlled so that the wastes are preferentially used

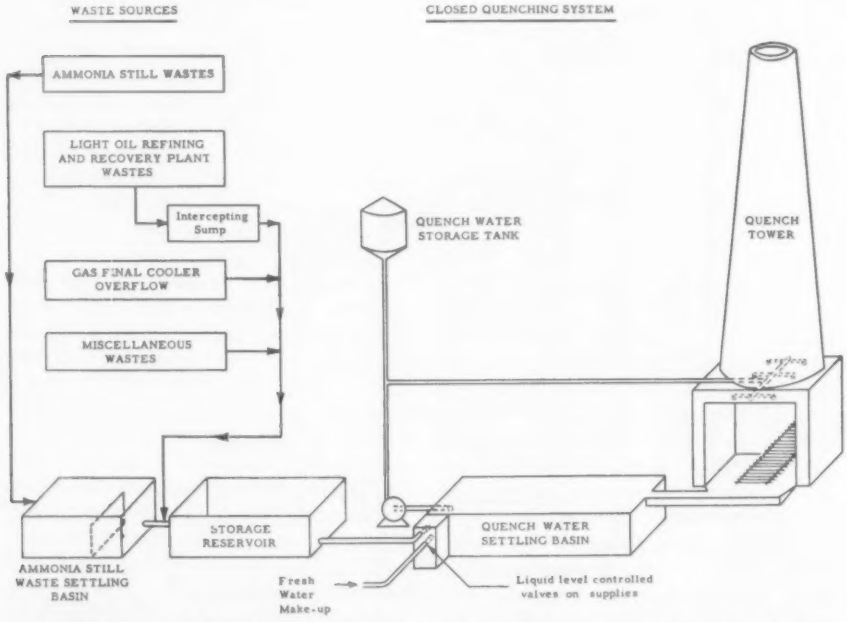

FIGURE 7.—Schematic diagram of a coke quenching system for disposing of all liquid wastes.

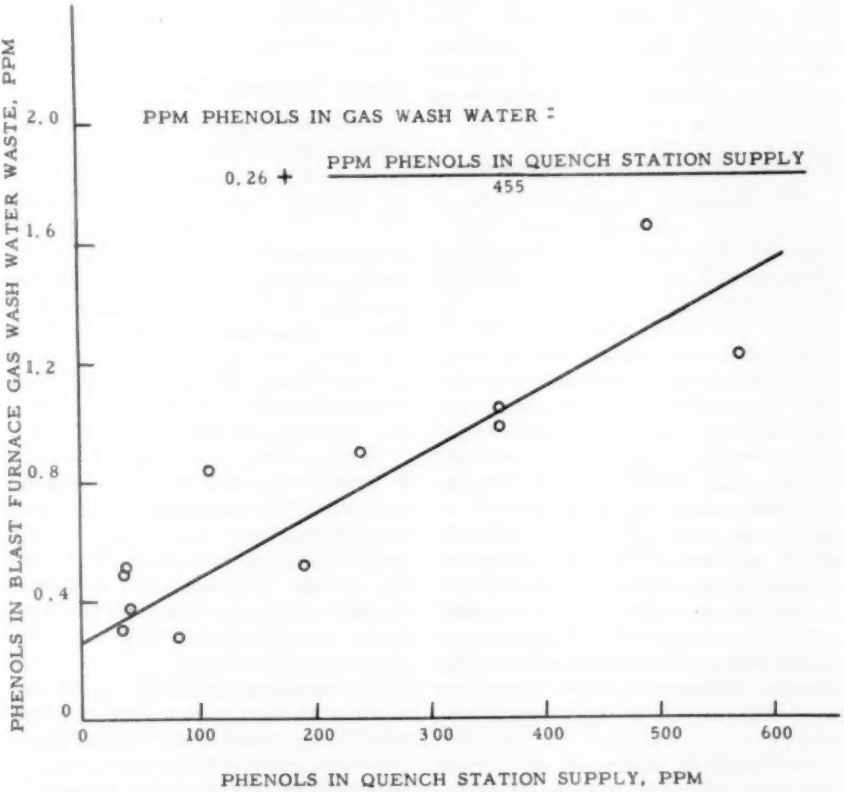

FIGURE 8.—Relationship of phenols in quench station supply and blast furnace gas wash water waste.

for the quench rather than the supplemental supply.

Some of the materials in the water of a closed-quench system (Figure 7) are entrained in and deposited on the coke. The phenolic odor and the discoloration from deposition of salts preclude domestic use of such coke. These changes in the coke are likewise reflected in the blast furnace department. It has been suggested that deterioration of blast furnace lining may be accelerated by the use of coke quenched with the high chloride still waste. Phenolic materials entrained in the coke appear in the blast furnace gas wash water as shown in Figure 8. These data were obtained by varying the amount of phenols in the quench water and measuring phenol residual in the blast furnace gas wash water when this contaminated coke was a part of the furnace charge. Correlation of blast furnace operations with coke waste data indicate that phenol carryover in the blast furnace gas wash water may be expected to vary between 5 and 10 per cent of the phenolic content of the coke quench water (17).

Quenching coke with waste waters is beset with other objectionable features. The corrosive effect of these wastes, because of their chloride content, is apparent on all metal surfaces with which they come in contact. Such damage, though difficult to assess monetarily, must be charged to

this method of waste disposal. The contaminated vapors emanating from the quench tower may create an air pollution problem in a congested or built-up area.

Biological and Chemical Oxidation

The biological treatment of waste liquors from coal carbonization processes has been practiced extensively in England and to a limited extent in the United States (9) (13) (18) (19). Although gas works liquor common to England is not identical with by-product coke wastes, they possess very similar characteristics. The wastes can be combined with domestic sewage and treated in conventional treatment works. The Milwaukee and Chicago activated sludge treatment plants receive coke plant wastes. In England, much of the combined sewage is treated on percolating filters with the volume of gas works liquor being held to 0.5 per cent of the volume of combined wastes. Combined treatment has proven satisfactory where there was an adequate volume of domestic sewage.

Dephenolized ammonia still waste has been subjected to chemical oxidation on a pilot-plant scale (20). Chlorine, ozone, and chlorine dioxide have been used in the experimental work. The efficacy of treatment was demonstrated, but the cost for full-scale development was considered prohibitive.

Analytical Methods

Evaluation of the wastes discharged in the various phases of by-product coke operations makes it necessary to determine a number of chemical entities. Of these chemical components, phenols and cyanides are especially important. The analytical procedures for these materials have undergone revision as a result of research since the start of the coke waste studies reported herein. A brief summary of the various modifications used, together with a short discussion of their merit follows.

Phenol Determination

Three methods were used in the determination of phenols in by-product coke wastes. These methods consisted of Scott's bromination procedure, Gibb's colorimetric method using 2,6-dibromoquinonechlorimide, and the 4 aminoantipyrine method as originally proposed by Emerson. The modifications of this latter method as well as the other two methods are contained in the Tenth Edition of "Standard Methods for the Examination of Water, Sewage, and Industrial Wastes."

In the use of any of these methods, it is first essential that the phenolic compounds be separated from any compounds that might cause either positive or negative interference with the method. The screening procedure usually used, regardless of the analytical method chosen, may be briefly summarized as follows.

The sample is distilled from an acid solution in the presence of copper sulfate, which theoretically should eliminate nitrogen-base compounds, sulfides, and high-boiling organic compounds. (These latter compounds may also consist partially of high-boiling phenols.) The phenols, together with the organic acids and neutral compounds, are extracted from the acid distillate with chloroform. The chloroform is then serially extracted with sodium hydroxide leaving the neutral compounds in the chloroform layer. A further purification step has also been used in some cases. This additional step provides for distilling the caustic extract from an acid solution, again in the presence of copper sulfate. By the use of this screening procedure the phenolic compounds present in the original sample should be relatively free from interfering substances.

In using the bromination procedure for determining phenols it is doubly important that no compounds be pres-

TABLE VIII.—Comparison of Phenol Results Determined by Bromination and by Gibbs Methods for Various By-Product Coke Wastes

Sampling Point	Method and Sample Number											
	Scott's Bromination (p.p.m.)						Gibbs (p.p.m.)					
	1	2	3	4	5	6	1	2	3	4	5	6
Ammonia still*:												
Plant X	264	356	262	350	949	957	246	458	126	257	915	1,000
Plant Y	590	576	569	658	658	695	524	629	545	798	782	550
North quench	4.0	9.7	—	4.0	1.0	—	1.0	1.0	—	1.4	1.0	—
North outfall	8.5	8.5	6.0	13.0	16.0	9.9	7.0	8.5	4.0	16.0	25.0	8.9
Intercepting sump	308	324	533	328	353	266	292	388	306	292	333	298
Main outfall	10.0	13.3	14.5	13.0	13.0	66	28	13.5	11.0	19	13.0	71
Final-cooler water	356	434	380	368	424	399	329	420	400	334	342	312

* Different by-product coke plants.

ent (except phenolic) which would react with bromine, since this test is essentially a bromine-demand test. Typical examples of such interfering compounds which may be found in coke wastes are organic nitrogen bases, sulfides, ammonia, cyanides, etc. In using the bromination method, it is necessary to follow the detailed procedure as outlined by Scott, otherwise the data obtained may not be comparable to that obtained by the other methods. In the hands of a competent analyst, this method has been shown (Table VIII) to yield reasonably close check results with the Gibbs procedure.

The method which has been chosen most frequently is the Gibbs colorimetric procedure. However, it is still necessary to adequately screen the sample to remove interfering components. This is particularly true of reducing compounds such as the sulfides. Even when the complete screening procedure is used there may be phenolic compounds present in the final distillate which will not react with the Gibbs reagent. This is true of those phenolics which have a group (other than chlorine) substituted in a position para to the hydroxyl group.

Another important factor which enters into the determinations of phenolics by the Gibbs procedure is the sensitivity of this reaction to pH control. Fading of the color or complete decolorization will follow if the pH is allowed to fall below 9.2. The data in Table VIII show that if an adequate screening procedure is followed, plus the proper analytical control, satisfactory check results can be obtained on wastes from the coke industry.

The third method that was used in the later coke plant studies was the 4-aminoantipyrine procedure. This method can be carried out in less time than either of the other methods mentioned and it may be adapted to either high or low concentrations of phenols. Again, as with the other two methods, an adequate screening procedure must be used. As mentioned previously, in the Gibbs procedure para-substituted phenols are not determined, while with 4-aminoantipyrine, if the para-substituted group is a halogen, carboxyl, hydroxyl, or sulfonic acid, a positive reaction is obtained.

Comparative checks for phenols were made by the Gibbs and 4-aminoantipyrine methods on one coke plant effluent. The results are tabulated below:

Sample No.	Method	
	4-aminoantipyrine (p.p.m.)	Gibbs (p.p.m.)
1	40	34
2	17	13
3	47	49

In addition to these results, ammonia still waste has been analyzed

further for phenol by both the Gibbs and 4-aminoantipyrine methods on several occasions. On all of these samples the two procedures gave consistent checks on this particular waste.

Cyanide Determination

In the earlier coke plant studies, the tartaric acid distillation method was used and the cyanide absorbed in caustic was titrated with standard silver nitrate. This procedure is effective in the breakdown of simple cyanides but with complex cyanides the breakdown is less than by using the Serfass reflux procedure. With the type of cyanide components encountered in by-product coke wastes little difference would be expected in the results obtained in the two distillation methods. When the cyanide concentration was greater than 1.0 p.p.m., it was determined by titration; at lesser concentrations the pyridine-pyrazalone colorimetric procedure was employed.

Research Needs

These studies have revealed numerous areas for research. These include:

1. Identification of constituents responsible for toxicity to aquatic life.
2. Determination of the nature and persistence of non-phenolic taste and odor-producing materials.
3. Development of control or treatment methods to reduce the toxic, taste, and odor characteristics.
4. Assessment of the damages claimed for quenching coke with by-product coke wastes.

Summary and Conclusions

The research on which this guide is based has contributed to a greater understanding of the factors which influence by-product coke wastes and their effects on receiving waters. Analysis of the data collected during these several research projects leads to the following summary statements and conclusions:

1. The quantity of pollutional materials in ammoniacal liquor varies directly with the volatile matter in the coal charged to the ovens.
2. The temperature of carbonization has a significant effect on the production of phenols and cyanogen compounds; phenols decrease and cyanides increase with rise in coking temperature.
3. The pick up of pollutional material by the ammoniacal liquor, in the indirect ammonia recovery process, can be greatly reduced by preventing contact of ammonia scrubber water with flushing liquor.
4. Solvent extraction dephenolization systems can be designed and operated to remove more than 98 per cent of the phenols from raw ammoniacal liquor thereby preventing carry-over of phenols to the gas stream and subsequent processes.
5. The gas final-cooler water is a highly pollutional liquor but through the use of cooling towers and closed systems this liquor normally does not enter the sewers.
6. Benzol plant process wastes, though relatively small in volume, are highly toxic and may account for a significant portion of the toxicity observed in coke plant effluents.
7. It is possible to dispose of all liquid wastes in a closed coke-quench system; however, some of the phenolic materials are absorbed by the coke and appear in the blast furnace gas wash water.
8. Ammonia still wastes are amenable to biological treatment when combined with relatively large volumes of domestic sewage.
9. The evaluation of both phenolic and non-phenolic constituents in coke plant wastes is necessary to accurately estimate their taste and odor potential.
10. The toxic nature of by-product coke effluents has been demonstrated and several highly toxic component wastes have been examined.

Acknowledgments

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GRATIS ISSUE

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Stream Pollution

COOPERATIVE STATE–INDUSTRY STREAM STUDIES —LOWER FOX RIVER, WISCONSIN *

By A. J. Wiley and B. F. Lueck; and Ralph H. Scott and T. F. Wisniewski

Respectively, Sulphite Pulp Manufacturer's Research League, Appleton, Wis.; and Wisconsin Committee on Water Pollution, Madison, Wis.

This paper reports on the preliminary results of a cooperative state-industry research effort directed toward evaluation of conditions which which have developed on the highly industrialized section of a Wisconsin river. During a one-year period in 1955–56 intensive studies of stream conditions on several Wisconsin rivers were undertaken jointly by laboratory and field crews representing the State of Wisconsin Committee on Water Pollution and similar task forces from the pulp and paper industry. Two principal reports (1)(2), which include detailed data obtained from studies on the Lower Fox River, have recently been issued by the State Committee. Data from those two reports provide the basic information summarized in this paper. Methods developed in organizing these cooperative state-industry stream studies have been described elsewhere (3).

Changing Conditions on the Lower Fox

The Lower Fox River, extending from Lake Winnebago at Neenah-Menasha some 39 miles north to the river mouth at Green Bay (see Figure 1), is a prime example of the effects upon a stream brought about by changing population and environmental conditions which have taken place in the past 250 years from the earliest recorded history of the French and Indian fur trading days before 1700 to present-day conditions of heavy stream employment. This employment is for municipal and industrial water supply, for hydroelectric power development, for navigation, for recreation, and finally for waste disposal.

The Lower Fox River is a working stream. In any consideration of this stream and its proper place in the scheme of things, it is important to keep in mind that it has always been a working stream. Before man came to its valley in large numbers, the Fox performed the dual function of serving Nature not only as a drainage system but also as a treatment system that purified its waters when and as these were contaminated by natural wastes. Now it also performs these functions in the service of mankind. As is inevitable in any situation of a changing environment, some phases of the work which this river does for both Nature and man are changing. The basic problem in sound management of this river is to make sure that these changes are guided to permit the stream to carry out its many and varied functions to maintain maximum long-term benefits for all.

Exploitation of some particular employment for the river may, and often does, result in substantial changes and effects upon other functions of the river. As examples, may be cited the

* Presented at the 1956 Annual Meeting, Central States Sewage and Industrial Wastes Assn.; Green Bay, Wis.; June 20–22, 1956.

FIGURE 1.—Wintertime air view of Lower Fox River Valley.

construction along the Fox River of the navigation system and power dams, which together have had particular effects on the physical characteristics of the stream, and at the same time have produced great changes in its biological characteristics.

On the Lower Fox River there is a series of some 14 power dams backing up the water in pools as shown in Figure 2. The hydroelectric developments take advantage of the 166-ft. vertical drop in the 39 miles between Lake Winnebago and Green Bay. The change-over from long stretches of rocky bottom, washed free of silt and organic debris by fast water, to a series of settling ponds with silted bottoms is quite apparent. Stream biologists say that a concurrent change in the fauna and flora of a river must be expected when such physical changes occur during the development of hydroelectric power and navigation systems. However, dispassionate examination of all the facts refutes the claim sometimes made that the Lower Fox River has been ruined and despoiled by those physical changes which mankind has brought about and by the resultant adjustments which Nature has made to each major change in environmental conditions.

Data reviewed later in this report show clearly that the Lower Fox River has a large and important capacity for self-purification under present conditions. Manifestly, no conceivable effort aimed toward prevention of water pollution can restore the fast-water conditions of the fur trading days. The immediate problems, therefore, can be summarized as follows:

1. What is the working capacity of the Lower Fox River in terms of self-purification?

2. What sources of natural and man-made pollution contribute to the loading imposed upon the stream's working capacity for self-purification?

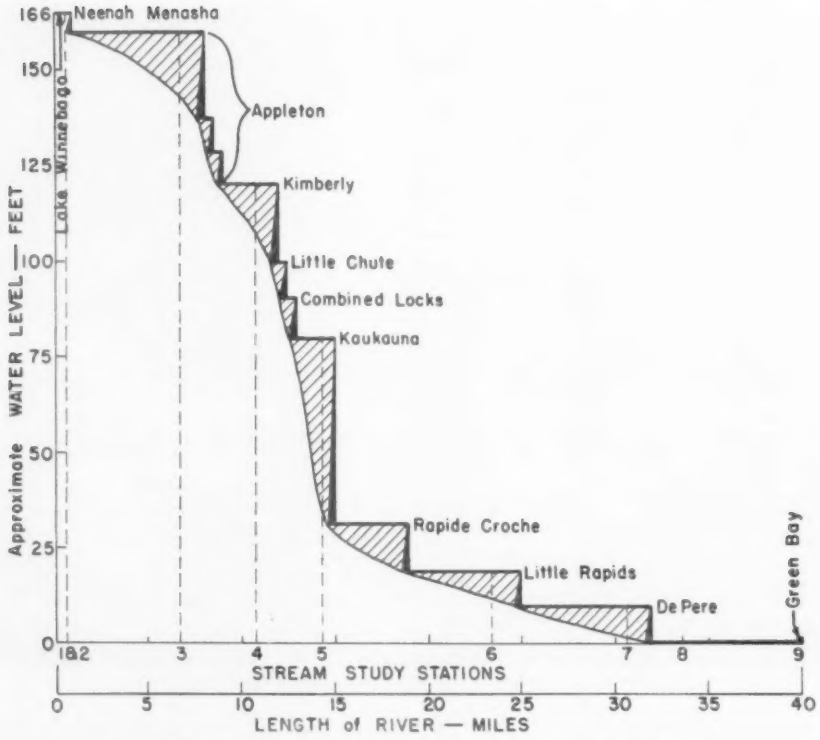

FIGURE 2.—Power dams and water pools of Lower Fox River.

Only when answers to these problems become available can it be expected to have the basis for setting up a control for water pollution on the Lower Fox which will be logical and at the same time allow this stream to work efficiently on all the uses which the growing populations require.

Evaluation of Chemical and Biochemical Factors

The 1955–56 cooperative surveys were particularly directed toward obtaining quantitative analytical data to supplement the standard qualitative stream survey data which have been collected on the river over a period of many years. Collection each year of hundreds of grab samples has been a standard practice and valuable information has been gained on river conditions from these studies. However, such information is essentially qualitative in nature and tells little more than the obvious fact that the stream is in a state of pollution or, conversely, that clean water conditions exist. The really significant task is to determine the amount of work the stream can do, find the degree to which the stream can be safely loaded, and then develop a program to keep the loading within the stream's working capacity.

To obtain quantitative data on a large river necessarily requires trained field and laboratory crews to collect many samples at each station to be studied on the river. It also involves study of a number of stations along the length of the stream, both above and below the known sources of stream loading.

Figure 3 shows one of the survey

crews in action on the Lower Fox River. At this point the stream was divided into 20 sections across its width and the position of the boat for each section was accurately checked with a transit on shore and a stadia rod mounted on the boat. Current meters were used to check the stream flow for each section, and samples were collected at 0.2 and 0.8 depth for each section across the stream. Samples were analyzed for B.O.D., dissolved oxygen, deoxygenation rates, suspended solids, and also for organic matter resistant to biological degradation, by means of the Folin and Denis test, which provides a measure of substances containing the aromatic hydroxyl group. Auxiliary data on temperature and pH of the water and on other sampling conditions were carefully recorded.

Nine sections along the length of the stream were surveyed during four separate periods running from April through June, July, and October. Excellent data were obtained throughout the survey. However, the results obtained at Station 9 near the mouth of the river at Green Bay were confusing and difficult to interpret due to wind and current effects circulating the water from the bay in and out of the river mouth.

Data for dissolved oxygen and B.O.D. assays are shown graphically in concentration profiles for Figures 4 and 5. In the April survey (Figure

FIGURE 3.—Field crew and equipment for Fox River study.

4) the dissolved oxygen level of the water leaving Lake Winnebago at Stations 1 and 2 was high (13 p.p.m.). This was believed due to photosynthesis action of algae, which contributed to a certain degree of supersaturation even at low water temperatures. The dissolved oxygen concentration remained high (above 8 p.p.m.) for the entire length of the stream. The B.O.D. of the water leaving Lake Winnebago was about 5 p.p.m. during the high water period. This high B.O.D. was at first thought to be primarily due to suspended matter being carried by the spring flood, when flows ranged upwards of 7,000 c.f.s., as contrasted with later flows, dropping to the 1,500-c.f.s. level in October. However, there is evidence that the growth of algae in Lake Winnebago may be a year-round problem and it is probable that algae were contributing to the B.O.D. even that early in the year.

As the surveys progressed downstream, the B.O.D. increased appreciably below Appleton to Kaukauna, where major sources of municipal and industrial wastes enter the stream. The highest concentration of B.O.D. ranged around 8 p.p.m. in that area of the stream, but a noticeable reduction in the working load was apparent below Station 6.

In the second survey, conducted in June, the stream flow had decreased to

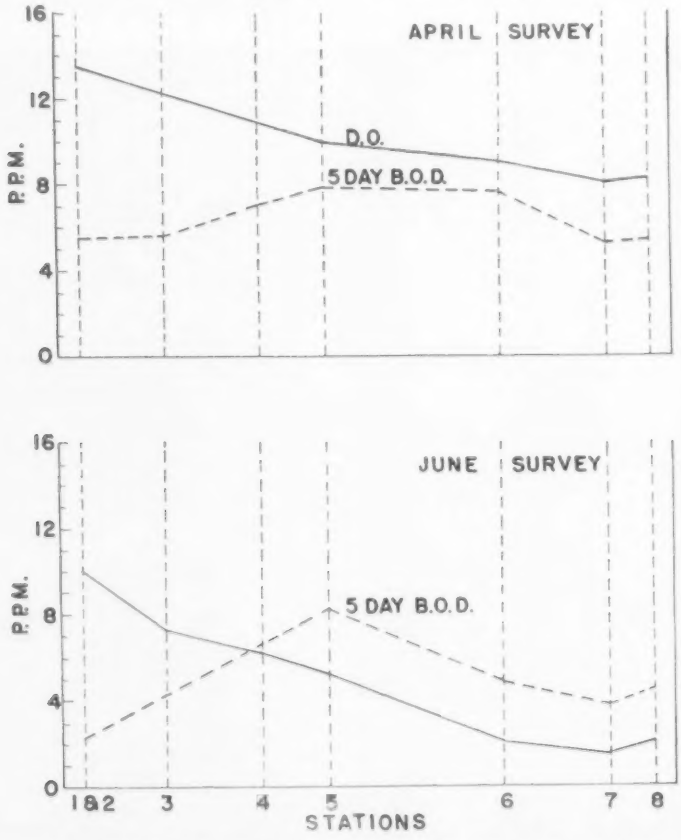

FIGURE 4.—B.O.D. and D.O. concentration profiles for April and June surveys.

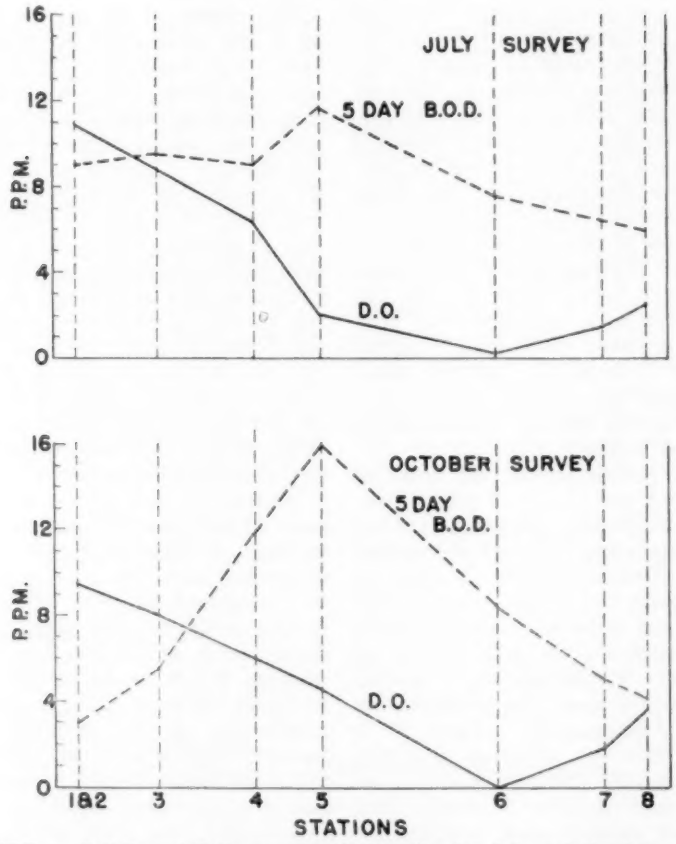

FIGURE 5.—B.O.D. and D.O. concentration profiles for July and October surveys.

about one-half that for the April survey, ranging from about 3,400 c.f.s. at Neenah and Menasha to more than 4,000 c.f.s. at the river mouth. Water temperatures had increased from less than 15° C. during April to a higher level ranging from 20° C. at the source to 24° C. near the mouth. These physical conditions of the river noticeably affected the dissolved oxygen concentration of the water as it progressed downstream. The water from Lake Winnebago was at the point of oxygen saturation, but dropped steadily to 6 p.p.m. above Appleton, 4 p.p.m. below Appleton, and decreased further to about 2 p.p.m. at Stations 6 and 7.

The 5-day B.O.D. values of the waters from Lake Winnebago were about 2 p.p.m. and increased steadily to 8 p.p.m. at Station 5 below major sources of pollution in the Appleton to Kaukauna area. Beyond Station 6 (below Kaukauna) the working capacity of the stream for self-purification was plainly evident. The B.O.D. dropped steadily with the concurrent drop in the dissolved oxygen. Evidence of recovery of the stream from its top loading of B.O.D. in the midsection was apparent at Station 8 (below De Pere) in these surveys. As the oxidation of the stream loading approaches completion in this area of the stream, the demand for oxygen de-

creased and natural means of reaeration could bring about a noticeable increase in the dissolved oxygen level.

Concentration profiles for the July and October surveys are shown in Figure 5. In each, high levels of dissolved oxygen are found in the waters leaving Lake Winnebago. In July much evidence was found of oxygen supersaturation by photosynthetic action of algae at Stations 1 and 2. Water flows were lower, however, with less than 3,000 c.f.s., and the water temperatures were very high, ranging from 27° C. to 30° C. The very heavy algal bloom experienced in Lake Winnebago during the July survey will be discussed further.

From the source of the river at Stations 1 and 2, the dissolved oxygen concentration dropped to critical levels below Appleton and approached zero at Station 7 above De Pere, at which point the working load of the stream had apparently been substantially satisfied. The B.O.D. value of the Lake Winnebago water having high levels of algal cells in suspension during July ranged upwards of 8 p.p.m. This was increased to nearly 12 p.p.m. by further loadings of B.O.D. received below Appleton. But the river showed much evidence of working capacity to reduce this B.O.D. loading in the stretches downstream to Station 7, and again evidence was found of rising D.O. concentrations between Stations 7 and 8.

In October the water flow had decreased to about 1,500 c.f.s. at Stations 1 and 2 and the temperature of the water was less than 12° C. The 5-day B.O.D. concentration of the water entering the river at Stations 1 and 2 had dropped to about 3 p.p.m., but it had increased to the highest level of the year just above and below Appleton. It seems possible that the high B.O.D. value which was evident above Appleton came from decomposition of sludge beds which had accumulated in the pool formed by Little Lake Butte des Morts.

The results of the stream surveys up to this point not only provide accurate confirmation of results from the qualitative data obtained from grab sampling programs in previous years, but also provide wholly new information. There is no doubt that the Lower Fox River is carrying a very heavy work load for self-purification at all times of the year, but the total loading from both man-made and natural sources is especially high during the warm summer months when the stream is least capable of providing the extra amounts of dissolved oxygen needed for oxidation reactions. At this stage of the stream study the value of the newly available quantitative data becomes apparent.

Figures 6 and 7 give a brief summary of pertinent information on the loadings of ultimate B.O.D. and of suspended solids for comparison with the calculated amounts of dissolved oxygen available per day. In the April survey, at Stations 1 and 2, the ultimate B.O.D. at 20° C. amounted to about 160 tons per day. This determination of the loading was apparently confirmed by the presence of about 140 tons daily of volatile organic matter as suspended solids. To handle this loading, the river at its source carried approximately 260 tons of dissolved oxygen. Below Appleton, at Station 5, the ultimate B.O.D. loadings had increased to about 190 tons and the dissolved oxygen level had been decreased by work done to some 200 tons per day. At Station 8, below De Pere, the ultimate B.O.D. loading had been decreased to about 150 tons daily and the dissolved oxygen level to 185 tons daily. There was more than enough oxygen available to handle the entire working load all the way downstream.

In the second survey, conducted in June during lower water flows and at higher temperatures, the B.O.D. loading was approximately 40 tons daily and the dissolved oxygen available was about 90 tons at Stations 1 and 2. At

Station 5, the B.O.D. had increased to 155 tons daily and the oxygen available had decreased to 60 tons per day. At Station 8, the B.O.D. loading was about 160 tons and the dissolved oxygen available had further decreased to about 27 tons per day. The stream was heavily loaded much of its length in the June survey.

In Figure 7, data for the July survey show 280 tons of B.O.D. daily at Stations 1 and 2 and only 84 tons of dissolved oxygen available. Heavy blooms of algae were evident in the lake at that time and it seems quite possible that natural sources of organic matter, of which algae may be a large proportion, were, under adverse conditions, contributing a heavy loading upon the river waters. The evidence for this high loading was substantiated by the volatile suspended solids data and by the lower level of dissolved oxygen of the waters for the entire length of the stream. At Station 5, the B.O.D. loading had decreased to 140 tons and only 15 tons of dissolved oxygen remained. At Station 6, below Kaukauna, the B.O.D. loading reached a peak of 420 tons daily and less than 0.25 ton of dissolved oxygen remained available. By the time it reached Station 8, the B.O.D. loading was greatly reduced to 155 tons and the dissolved oxygen available had already increased to 23

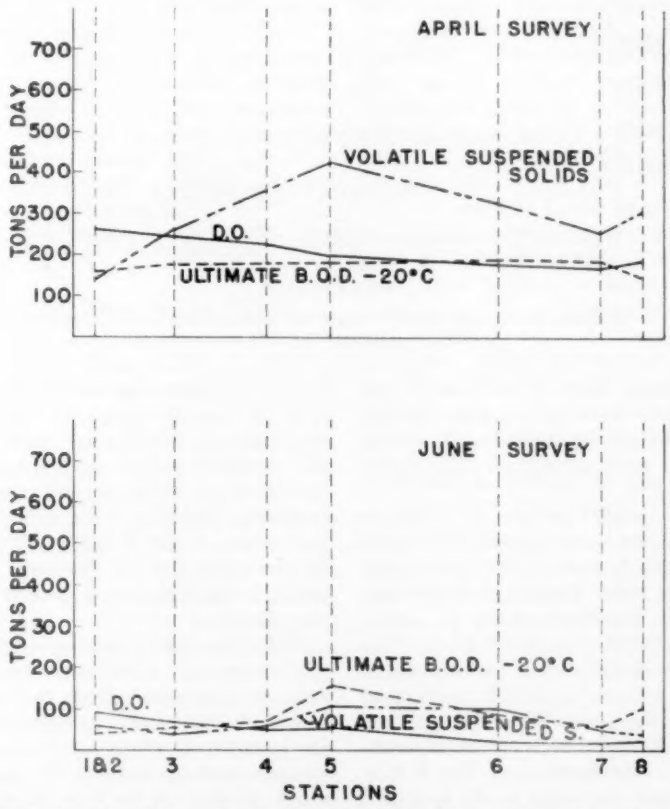

FIGURE 6.—B.O.D., D.O., and volatile suspended solids loading and working capacities during April and June surveys.

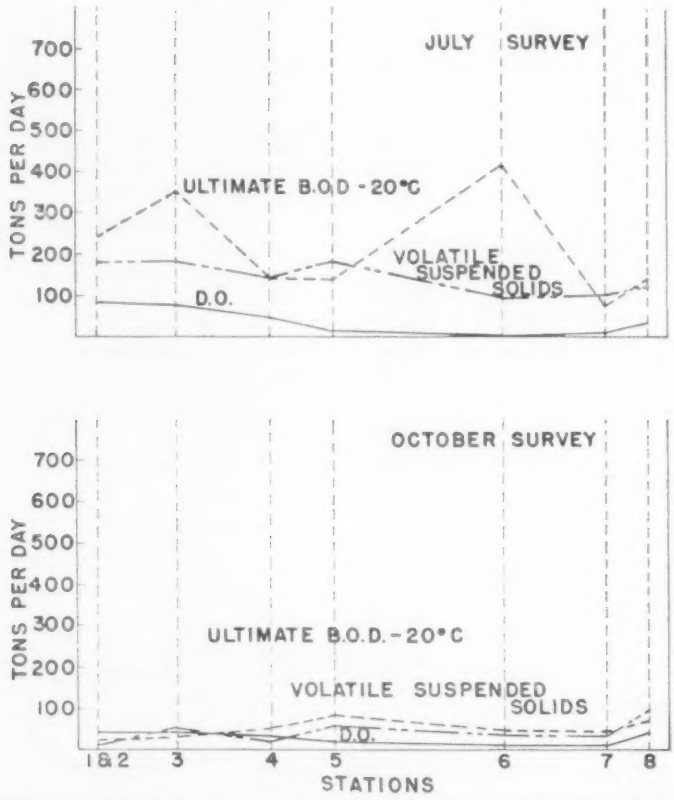

FIGURE 7.—B.O.D., D.O., and volatile suspended solids loading and working capacities during July and October surveys.

tons. Again there is evidence of the remarkable working capacity of the stream below Station 6 and of its ability to start recovery in the region of Station 8.

In the October survey, the ultimate B.O.D. of the water entering the river at Stations 1 and 2 (28 tons daily) was much lower than in the other surveys, but the dissolved oxygen available amounted to only 38 tons. This may be evidence of self-purification of the late summer and fall loading of algae in the Lake Winnebago waters before entering the river at Neenah-Menasha. At Station 4, the B.O.D. loading had increased to 50 tons and the dissolved oxygen available decreased to 25 tons daily. The loading of B.O.D. increased in the Appleton area by some 30 tons to a level of 82 tons daily at Station 5. At the same station the dissolved oxygen level had decreased to 21 tons, and decreased further to less than 1 ton at Station 6. At Station 8, the B.O.D. loading was 76 tons daily, but the dissolved oxygen available had increased greatly to 33 tons daily.

Although the possibilities for the occurrence of significant errors in making calculations from the first attempt at obtaining quantitative data are recognized, there are nevertheless valuable new indications of conditions which prevail on the Fox River from early spring through the fall months. There can be no doubt that the total

sources of natural and man-made wastes entering the river contribute high loadings of readily decomposable organic matter requiring large amounts of oxygen for biological oxidation reactions. During the warm summer months the lower stream flows and the decreased amount of oxygen available from all sources contribute heavily to prevalence of the critical oxygen conditions which existed in the waters of this river. It is to be expected that when the amount of oxygen decreases to the point of exhaustion, the effective capacity of the river to handle the total amount of these two sources of wastes is greatly reduced. Nevertheless, the river shows a striking capacity for oxidizing its working load of organic materials, even under adverse conditions.

Figure 7 shows the striking contrasts in the stream loadings, in terms of ultimate B.O.D. and suspended volatile solids, which occur during the hot weather peaks, when dissolved oxygen levels and working capacity are lowest, as compared to low levels during cool weather in the late fall months.

Effect of Algae on the Stream

The survey observations have provided a new finding, which is not only important, but also is actually basic, on stream conditions prevailing in the Lower Fox River. It is now apparent that natural sources of pollution can become a controlling factor in stream conditions and this status may even prevail throughout the year. Reference is made especially to indications that growth of algae in Lake Winnebago contributes large amounts of organic matter that apparently decompose within this stretch of the Lower Fox River, and thereby create a huge demand on the limited supply of dissolved oxygen that the river can be expected to have available for the total working load of both the man-made and the natural wastes.

On the other hand, a special survey conducted by state officials during the 1955 July 4 holiday period indicates that stream conditions during critical hot weather periods improve materially when a portion of the overload from total sources has been reduced by the decrease in industrial wastes.

Visual evidence of the large amounts of algae growing in the waters of Lake Winnebago and Green Bay can be seen when the heavy blooms occur. The shallow shoreline waters in some areas become green and nearly opaque with the heavy suspensions. Wave and wind action at times tend to deposit some of this green cell material along the shoreline. There is also much evidence that this material may settle out in certain areas to form sludge beds, with resultant slow decomposition and formation of characteristic floating masses of rising sludge derived from this settled organic matter. These masses, supported by gas bubbles produced in slow anaerobic fermentations, rise and float on the surface during hot weather.

Much remains to be learned about the reactions of living and dead algal cells in natural waters. Conferences have been held with authorities interested in this problem at the University of Wisconsin. A comprehensive research program to further delineate the significance of algae in stream pollution problems is in prospect under state and industry sponsorship.

Biological Survey of the Lower Fox River

A biological study of stream conditions during 1955–56 was conducted by aquatic biologists of the State Committee on Water Pollution and of the staff of The Institute of Paper Chemistry. This work (2) complements earlier and similar studies of this river and serves to confirm results of the chemical and physical studies. Figure 8 provides comparative information on the species of tolerant and intolerant aquatic bottom dwelling organisms found along the various

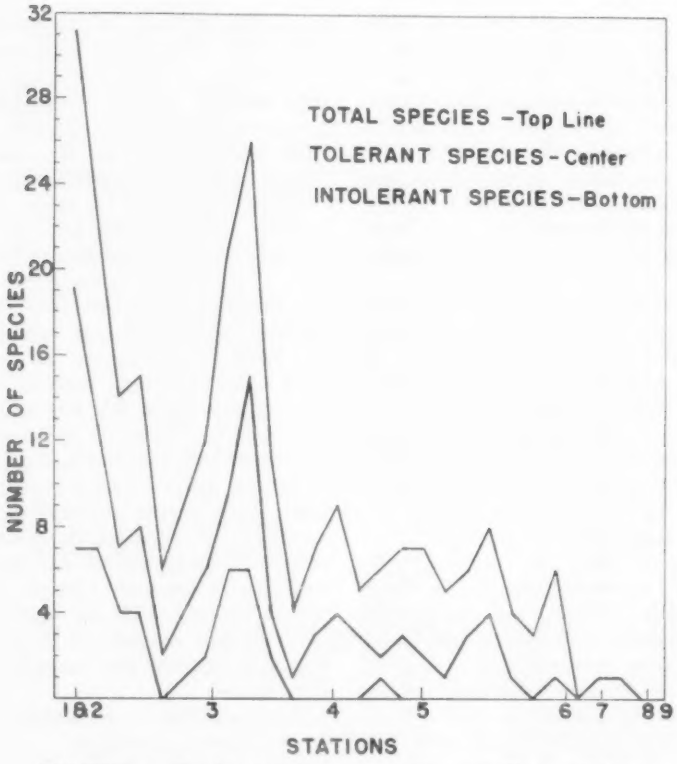

FIGURE 8.—Species distribution of bottom-dwelling organisms.

stretches of the river at some 28 stations selected for the bio-survey (2). Organisms indicative of low average organic loadings were found in the river waters at Stations 1 and 2 in Neenah-Menasha, but from that point downstream the intolerant forms decreased in number. Total species were also found in decreasing numbers downstream, with tolerant organisms in preponderance. Just above Appleton a large increase in numbers of species occurred in the area of Little Lake Butte des Morts, where river conditions indicated a partial recovery from waste loadings introduced at Neenah and Menasha.

Summary and Future Work

The combined chemical, physical, and biological studies made on the Lower Fox during 1955–56 have served to confirm previous river surveys in showing much evidence that the stream receives such heavy total loadings of fermentable organic matter from natural and man-made wastes that it develops critical conditions of low dissolved oxygen below major sources of such wastes. Maximum stream loadings occur especially during hot weather, when the available oxygen supply is usually at a minimum.

These studies indicate that further and more detailed studies of the algae problem will be required to assess accurately the amount of organic matter derived from this source and to learn more of its effect upon the stream. However, the data from these studies are sufficiently advanced to permit an estimate that some stretches of the

Lower Fox River may be receiving as much as 400 tons of organic matter daily from combined sources of natural and man-made wastes. Of the total amount, it seems apparent that a very substantial portion derives from natural sources, such as the growth of algal blooms on Lake Winnebago, for extended periods of the year and especially during the hot weather periods of critical oxygen depletion in the river waters.

The working load contributed by sludge beds in the river is difficult to assess from data thus far available. But this, too, appears to be a significant factor in stream conditions which prevail during hot weather periods. It probably also contributes to the biological picture the year around.

For the first time information is now available as to the remarkable working capacity of the stream for self-purification. Large proportions of the total loading of natural and man-made wastes are decomposed and the oxygen demand satisfied in the stretches of the stream above Green Bay. Further research and evaluation should make it possible to utilize this working capacity properly and with proper control to avoid much if not all of the adverse conditions of oxygen depletion now experienced.

Large possibilities for improving stream conditions on the Lower Fox River exist through reducing industrial and municipal waste discharges. It is conceivable that ways also will be learned in which to help the river assimilate and purify wastes derived from such natural sources as algae growth and from the sludge cover on the stream bed within the settling pools formed above the power dams. In addition to those obvious possibilities for reducing the loading of organic matter received by the stream, practical ways may eventually be found in which to increase the oxygen supply of the stream in critical warm weather periods.

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2. Balch, R. F., Mackenthun, K. M., Van Horn, W. M., and Wisniewski, T. F., "Report WP102." State Commission on Water Pollution, Madison, Wis. (May 4, 1956).
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AMERICAN SANITARY ENGINEERING INTER-SOCIETY BOARD

The first certificates were awarded at the recent annual meeting of the American Sanitary Engineering Intersociety Board. Approximately three-quarters of the more than 200 applications considered were approved for certification without examination. Each successful applicant will be certified in one of the following five areas of "special qualification": Water Supply and Waste Water Disposal, Public Health Engineering, Industrial Hygiene, Radiation Hygiene and Hazard Control, and Air Pollution Control.

The first written examination will be given during 1957.

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

MORE POWER TO THE LADIES!

"The eyes of Texas" (sewage works personnel, that is) have turned in admiration upon the recent activities of the TWSWA ladies. After many years of attending the annual short courses and the meetings of the Texas Water and Sewage Works Association with their husbands, these women came to the conclusion they could make a real contribution to the profession. Accordingly, at the March 1956 Short Course, they organized a State Auxiliary. The idea met with immediate, enthusiastic response and, in just a few months, the membership has increased five-fold.

The TWSWA State Auxiliary was originally organized for the purpose of planning activities that would make the meetings they attended more entertaining and enjoyable for their husbands and themselves. In this they met with immediate success—everyone concerned agrees that the Auxiliary is a top-notch morale booster. However, its potentialities for greater service were soon apparent. Through their official publication, "The Pipette," a quarterly journal-in-miniature, they have already undertaken the task of arousing greater interest in the annual short schools and the association meetings. Further objectives of the Auxiliary are the encouragement of higher standards of public health and the publicizing of the great professional opportunities in the water and sewage works field. It is the intention of the Auxiliary to expand its program to include educational and philanthropical activities, and plans are already underway for the establishment of scholarships for study in sanitary engineering and for the organization of traveling technical libraries.

The Federation welcomes this new organization and heartily endorses its program. It is hoped that this idea will spread and that similar auxiliaries will be formed in conjunction with other Member Associations of the Federation. It has been gratifying to note the gradual increase each year in the number of women attending the Annual Meetings of the Federation. Fifteen years ago it was not the custom but we have moved with the times and, beginning with the Silver Anniversary Meeting in 1952, an average of 200 ladies have been registered at each of our Annual Meetings. This indication of pride and interest in the profession is encouraging to everyone and it is hoped that the trend will continue.

The organization of the TWSWA State Auxiliary can have far-reaching effects, within the Member Associations and on the profession as a whole. Its members will be glad, we know, to pass along the "know-how" they have gained from experience to other individuals or groups interested in organizing similar Auxiliaries and we will all benefit—individually and collectively—from the knowledge that they are backing us 100 per cent. More power to the ladies! D. P. S.

TRICKLING FILTERS AND OPERATION TIPS*

By George T. Lohmeyer

Superintendent, Sewage Treatment Plant, University of Florida, Gainesville, Fla.

The trickling filters employed today as one method of secondary sewage treatment probably had their origin in the intermittent sand filter devised by Sir Edward Franklin in 1871. The sand filter produces a plant effluent of nearly drinking water quality through the biological breakdown of sewage organic matter as it passes through two or more feet of sand into an underdrain system. However, since one acre of sand filter area is required for each 1,400 people, efforts were made to devise a method of treatment which would reduce the space requirements.

The contact bed marked an effort to reduce the size of the sand filter. In this method of treatment, a concrete tank filled with rock was flooded with sewage, allowed to stand for several hours, and after the sewage had undergone a biological breakdown the tank was drained. To assure some degree of treatment, a dosage rate of only 60 gal. per cubic yard of filter rock was used. This method of treatment was abandoned because of its gross inefficiency. It did, however, mark a transition between the intermittent sand filter and the trickling filter.

The famed Lawrence Experiment Station of the Massachusetts State Board of Health is generally credited with setting up the first experimental trickling filter. In 1889, two small gravel filters were studied by this station and the basic principle of trickling filter operation was presented; that "a slow movement of sewage over biological slimes" would produce an increase in the stability of the dissolved and finely divided solids in a settled sewage. Today, this same principle is still fundamental.

An Englishman, Joseph Corbett, in 1893 applied the trickling filter principle of the Lawrence Experiment Station and added a means of applying the sewage in a spray. He also initiated the use of a "false bottom" in a trickling filter to support the filter media. The false bottom also provided ventilation and prevented clogging of the filter at the floor level.

The first municipal sewage treatment plant in the United States to employ a trickling filter was designed for Atlanta, Ga. in 1903. Other installations followed in Reading, Pa., and Columbus, Ohio. More than one-half of the military sewage treatment plants constructed during World War II were trickling filter plants. Today, trickling filters are the generally accepted method of secondary treatment. The treatment of numerous types of industrial wastes, including beet, yeast, slaughter house, textile, and even phenolic wastes, is successfully handled on trickling filters.

Filter Theory

Although man can be proud of his use of concrete, tile, steel, and power in the construction of trickling filters, the principles of treatment involved have been present since life first appeared on earth. Any stream of flowing water with an ample concentration of dissolved oxygen, and providing the presence of biologically inhibitory substances are sufficiently low, will gradually reduce the quantity of organic matter present, provided no additional pollution is discharged into the stream. This self-cleansing action of the stream is possible through the cooperative efforts of a variety of flora and fauna such as bacteria, protozoa,

* Presented at the 1956 Florida Water and Sewage Works Operators Short Course, May 28–June 2, 1956.

algae, fungi, worms, and insect larvae. These organisms utilize as food, either the organic matter present in the sewage or other organisms which subsist on the sewage solids. The net result is referred to, if it is accomplished in the presence of an adequate supply of dissolved oxygen, as a biochemical oxidation process. A satisfactory biological condition exists when there is an adequate supply of oxygen to support a multitude of aerobic organisms, which use as a food source, either directly or indirectly, the organic matter held in solution or suspension by the flowing stream.

The self-purification factors of a stream, namely, the presence of oxygen, aerobic organisms, and a food supply, are established in the trickling filter. A trickling filter is an artificial bed of inert material called media or aggregate covered with a naturally formed biological slime or zoogleal mass over which settled sewage trickles. The complex population of organisms making up the zoogleal mass consists principally of aerobic forms, those that require dissolved oxygen for their life processes. The proper dissolved oxygen level is usually provided by a natural ventilation system in the filter, which consists of a number of vertical shafts extending from the media surface to the underdrain system. The liquid collected contains organic material consisting of the products of oxidation, some of the various filter organisms, and the finely divided humus which sloughs from the filter media. Actually the trickling filter is not a filter in the sense that particles are filtered or strained out. Since the spaces between the media are large, a mechanical straining action will not result if the media is properly selected and placed. In fact, if a straining or filtering action should occur at any level in the media a severe ponding condition will result.

There is a divergence of opinions concerning the exact action which takes place within the filter. Although it is realized that the liquid passes through the filter in 20 to 30 min., the organic solids are believed to be trapped by the gelatinous slimes on the media and held for days before they are "worked over" by the microorganisms. The organisms in the outer slime layers are known to be aerobic. There is reason to believe, however, that the organisms in the deeper recesses of the filter are anaerobic. In spite of this, the biological action of trickling filters, from the standpoint of efficient operation, must be considered to be a completely aerobic process.

Filter Structure

Although trickling filters are usually classified as either standard-rate or high-rate the two types differ only slightly in physical appearance. Generally, a trickling filter (Figure 1)

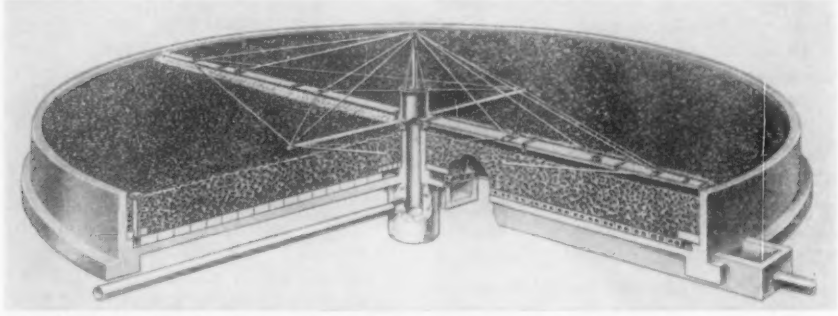


FIGURE 1.—Sectional view of a trickling filter showing basic construction features.

is composed of a distribution system which spreads settled sewage over a bed of media supported by a tile underdrain system. This underdrain system, designed also to provide ventilation, is supported by a floor which slopes to a collection channel. The filter media is generally held in place by a retaining wall. Settleable solids in the trickling filter effluent are removed in final sedimentation tanks.

Distribution System

The early trickling filters were equipped with a dosing siphon which discharged through a distribution system of fixed nozzles onto a rectangular filter bed. It was believed that trickling filters required a resting or "breathing" period between loadings and, therefore, the old standard-rate trickling filter was always equipped with a dosing siphon. Later experience has disclosed that a rest period is not necessary, in fact better operational results are obtained with continuous uniform loading. Furthermore, the fixed nozzle systems required a considerable hydraulic head. Today, trickling filters are generally equipped with reaction-driven rotary distributors which require less head. Occasionally, motor-driven distributors are used.

The general type of rotary or "lawn sprinkler" distributor consists of a hollow vertical center column carrying two or more radial pipes or arms; each arm has a number of nozzles through which the sewage is sprayed onto the filter bed. These nozzles all point in the same direction at right angles to the arms. The settled sewage enters the distributor through a line laid under the filter media (Figure 1). Generally, the lower stationary part of the distributor is separated by a mercury seal from the rotating section, although grease seals are sometimes employed. The rotating action results from the reaction to the discharge through the nozzle orifices. The orifice arrangement is designed for a uniform distribution over the entire surface of the filter. Various types of nozzles are manufactured but the basic purpose of a nozzle is to achieve a distribution of the sewage by means of splash plates or other devices. This results in a slight dissolved oxygen pickup in the sewage entering the filter and a minimum of direct washing of the media. The distributor arms are supported by guy-rods and air release lines are provided at several points on the upper side of each arm. Quick opening gates are provided at the ends of the arms for cleaning purposes.

Media

The purpose of the filter media is to provide a surface on which the organisms living in the filter can attach themselves. Since a trickling filter is made for many years of service the media material should effectively resist chemical and physical disintegration. Large-size gravel, pine slabs, tin cans, and even brick bats have been used successfully. However, blast furnace slag (Figure 2) is the generally accepted media because of its strength, lack of fine material, cubical shape, and its pitted surface, which provides a tremendous surface area for the organisms to cling to.

The depth of the filter media may vary considerably (from 3 to 16 ft.) but generally it is between 6 and 8 ft. The size of the media is an important factor. Although the smaller the media the greater the media surface area, excessively small media will clog readily. It has been reported that the surface area of a filter filled with 2-in. stone is twice the surface area of a filter containing 4-in. stone.

Underdrain System

The underdrain system for trickling filters generally consists of manufactured vitrified clay blocks (Figure 2) designed to carry the dead load of the

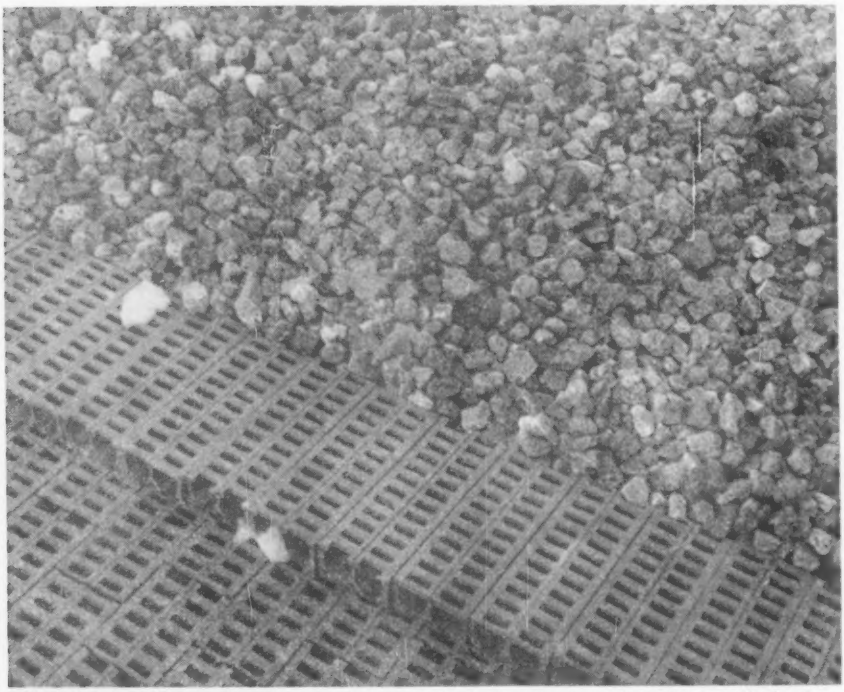


FIGURE 2.—Filter underdrain system of vitrified clay blocks. The filter media is slag.

wet media. The purpose of an underdrain system is twofold: (a) to collect the filter effluent promptly and (b) to provide a natural ventilation system. The collection flume is generally designed to flow half-full at maximum hydraulic load so that air can circulate throughout the media. To provide more air circulation, vertical clay pipe shafts are installed to extend from the media surface to the underdrain system, and are placed at regular intervals around the circumference of the filter.

The poured concrete floor beneath the media should be watertight and made as smooth as possible, since a rough floor will collect solids.

Walls

Trickling filters have been constructed without walls, the media graded to a stable slope. Some filter designs have used fencing to retain the media. Accepted practice is to construct walls of reinforced concrete. It is advantageous from the standpoint of plant operation to have solid walls because occasionally filter flooding is a necessity. Although more ventilation is provided without a filter wall, the disadvantages of this type of construction generally outweigh the advantages.

Standard-Rate and High-Rate Trickling Filters

Although the physical appearance of the standard-rate and the high-rate trickling filters closely resemble each other, there is a considerable difference in the loading rates and the degree of treatment obtainable with each. Both filter types are extremely reliable. They have an exceptional ability to withstand overloads and shock loads, and their operation is relatively

simple when compared with the activated sludge process.

Standard-rate filters use a dosing tank and siphon to shut off the flow to the distributor when the head falls below the level necessary to rotate the arms. High-rate filters provide for the continuous dosing of the filter. Recirculation of filter or secondary clarifier effluent is provided in most designs to maintain a continuous flow to the filter. Pumps are used and the recirculation system is frequently a proprietary design.

High-rate filters, normally comparatively shallow in depth, recirculate all or part of the filter discharge back to the filter. The recirculated flow may be filter effluent, or secondary clarifier content, underflow or effluent. Recirculation reduces the B.O.D. of the flow to the filter and results in a reduction to a lower B.O.D. than would result from a single passage through the filter.

The standard-rate trickling filter requires a greater volume of media and a larger distributor than does the high-rate filter and accordingly the initial cost is greater. However, the operation cost for the high-rate filter is greater because of the recirculation system required. High-rate filters have an advantage over standard-rate filters in that the degree of treatment can be varied by changing the recirculation ratio (recirculated volume/influent volume).

Both types of filters have certain disadvantages if careful operation is not followed. Nuisances caused by odors and psychoda flies are two of the greatest.

Trickling filter distribution, collection, and pumping systems must be designed to handle the hydraulic loading rates anticipated. At the same time there are limitations on the quantity of organic wastes which can be applied. Therefore, loading rates

TABLE I.—Comparison of Standard-Rate and High-Rate Trickling Filters

Feature	Trickling Filter	
	Standard-Rate	High-Rate
Hydraulic loading (m.g.a.d.)	Less than 4.0	From 10 to 30
Organic loading, B.O.D. (lb.):		
Per acre-foot per day	600	3,000
Per 1,000 cu. ft. per day	Less than 15	Over 30
Per cu. yd. per day	Less than 0.4	Over 0.8
Dosing interval	Not more than 5 min., generally intermittent but can be continuous	Not more than 15 sec., must be continuous
Sloughing	Intermittent	Continuous
Secondary sludge	Black in color, highly oxidized, light fine particles	Brown in color, not fully oxidized, fine particles, tendency to septicity
Effluent	Highly nitrified, into the nitrate stage, 20 p.p.m. or less B.O.D.	Not fully nitrified—generally only to the nitrite stage, 30 p.p.m. or more B.O.D.
Recirculation system	Generally not included but can be included if hydraulic loading is not exceeded.	Always included, although in some types recirculation is used only during periods of low flow.

must also express the organic B.O.D. loading which the filter can adequately handle.

Hydraulic loading rates are expressed as "millions of gallons per acre per day" (m.g.a.d.). Organic loading rates are expressed in terms of "pounds of B.O.D. per day per unit volume of media." The unit volume is designated as "per acre-foot," "per cubic yard," or "per 1,000 cu. ft." in the literature.

Table I presents data to compare the two types of filters in a number of their principal features.

Types of High-Rate Filters

High-rate trickling filters are generally loaded at 5 to 10 times the average hydraulic and B.O.D. loading of standard-rate filters. A number of patents have been obtained for high-rate trickling filters which involve either a method of spraying the settled sewage over the media surface or a method of recirculation. The following brief comments describe the pertinent features of each patent.

Accelo-Filter

The Accelo-Filter system has a relatively deep media depth, generally about 6 ft. A two-arm distributor is provided and a 2 to 1 recirculation ratio is recommended. The identifying characteristic of the Accelo-Filter is that the filter effluent is returned directly to a headbox where it mixes with the settled influent sewage. This recirculation system provides a means of reducing odors, increasing the concentration of dissolved oxygen, and continuously reseeding the influent sewage with active, hungry organisms from the filter.

Aero-Filter

A low momentary rate of application on a maximum area at one time is the characteristic feature of the Aero-Filter. This is accomplished by furnishing special distributors which provide a "raindrop" application on the media. Filters up to 34 ft. in diameter use a rotating disc whereas filters of larger diameters employ a special 8- to 10-arm distributor, which sometimes is rotated rapidly. Recirculation from the final clarifiers to the filter influent is provided for periods of low flows so that a minimum loading rate of 13 m.g.a.d. is maintained.

Biofiltration

The Biofiltration process is characterized by the recirculation of the filter effluent ahead of the primary clarifiers. This system requires larger primary and secondary clarifiers, but at the same time it provides a better consolidation of the solids in the primary tank. It also provides a highly flexible arrangement for operation of the clarifier. The depth of the filter media is relatively shallow, being 3 to 5 ft.

Other Types

Roughing filters are special high-rate filters used for reducing the B.O.D. of an excessively strong waste to a level which can be handled by conventional treatment methods. The Bio-Activation process utilizes a high-rate filter followed by an activated sludge plant.

Filter Operation

A trickling filter is not an independent treatment unit in itself, but depends on the entire sewerage system. Operational problems of trickling filters can sometimes be traced to faulty engineering, improper construction, or poor operation of the sewage collection system. Inadequate sewer line grades, excessive detention periods in lift station wet wells, and faulty operation of the system can result in a highly septic sewage reaching the sewage treatment plant, especially in warm climates. Septic sewage cannot be readily treated by the biological treat-

ment process which is utilized in the trickling filter.

The primary and secondary clarifiers, and the digester can impair the operational efficiency of the trickling filters.

The supplemental treatment units must be operated so the trickling filter will produce the best results.

Raw Sewage

The raw sewage entering the treatment plant should be as fresh as the design, construction, and operation of the collection system will permit.

Primary Clarifiers

The primary clarifiers should be operated so that:

1. Practically all the grease and floating solids are removed. If these solids are not removed they will clog the filter nozzles and the air spaces between the media. Grease will impair the filter efficiency by covering the zoogleal slimes with a layer which retards the absorption of oxygen, and it is a direct cause of odor.

2. A 30 to 35 per cent B.O.D. removal efficiency should be attained in the clarifier. The lower the B.O.D. of the filter influent the lower will be the B.O.D. of the filter effluent. Every part per million of B.O.D. removed in the primary clarifiers is just that much less load to be handled by the filter.

3. The clarifier sludge pumped to the digester should contain a minimum volume of water. For trickling filter plants without sludge thickeners the sludge solids content should be 3.5 per cent or more. Plants with sludge thickeners will produce a sludge of higher total solids. The ratio of raw sludge per day in gallons versus the influent flow in million gallons per day should be from 4,000 to 3,000 or less.

Any excess water pumped to the digester with the raw sludge will dilute the alkaline environment of the digester. If the digester is upset, the supernatant returned to the plant flow will carry an excess of solids, many of which will pass through the primary clarifiers to the trickling filter, all to the detriment of the trickling filter. The situation is complicated because any excess water pumped to the digester must leave the digester as supernatant.

Digester

The digester supernatant, if it is returned to the plant flow, should meet the following criteria:

1. Contain less than 0.5 per cent solids.
2. Be returned to the plant flow at either a slow rate throughout the day, or at a slow rate during periods of low night flow.

The author is of the opinion that supernatant should be returned to a trickling filter only if the plant is considerably underloaded. Best operation will result when the supernatant is kept out of the secondary treatment units entirely, particularly when the plant is operating at or above design capacity. A number of operators have accomplished this by disposing of supernatant on a partitioned section of an idle sludge drying bed. Another method is to discharge the supernatant to the plant lawn. The latter method is excellent for the lawn since supernatant is rich in plant nutrients but irrigation should be practiced only if: (a) the supernatant is in good condition, (b) the lawn is a thick mat of grass, and (c) the method of application prevents surface run-off of the liquid.

Secondary Clarifiers

The secondary clarifier sludge should be completely removed at intervals not exceeding two hours when the temperature is warm. Best operation

will result if the secondary sludge is pumped to the primary clarifiers for settling and consolidation before it is pumped to the digester.

Filter Problems and Solutions

Psychoda Flies

The small, moth-like, deceptively fragile fly whose dark brown, worm-like larvae live in trickling filter slimes is, in all probability, the biggest problem for the plant operator, especially during periods of warm weather. Such vast numbers of psychoda flies can inhabit a trickling filter that they are commonly called "trickling filter" flies. No problem will result from their presence if the fly population is held down to only a few flies in the immediate area of the bed. In fact, the larvae perform a useful function in the filter by constantly devouring the dead and dying zoogleal masses. Ponding of the filter occurs rarely when psychoda fly larvae are in a filter.

During the mild winter season experienced in the Southern states, the life cycle of the psychoda fly is from 2 to 3 weeks, but in the warm summer months the life cycle is reduced to 7 days or less. It is during these periods that the flies can emerge in such vast numbers that a real nuisance is created.

The adult flies are attracted to lights and for this reason they are a considerable nuisance in the immediate area of the treatment plant. Although the flight distance of the adult psychoda fly is relatively short, they can be wind-blown for a considerable distance. Control measures should be instigated before complaints occur.

In spite of the fragile appearance of the psychoda fly and larvae, the insect in both stages is extremely difficult to destroy. Most control measures depend upon destroying the larvae immediately before the adult emerges. The most severe infestations occur in standard-rate filters but high-rate filters, even those loaded at hydraulic rates of 30 m.g.a.d., may become infested.

The flies can be partially controlled by one or more of the following techniques:

1. Flood the filter for 6 to 8 hr.
2. Chlorinate the filter influent to maintain a 5 p.p.m. residual, thereby destroying the zooglea.
3. Use insecticides such as D.D.T., malathion, and chlordane when the filter is not in service.
4. Use a continuous hydraulic loading to hamper the flies and larvae.
5. Maintain clean grounds with close cropped grass and trimmed shrubbery.

Each of these control measures will, to some extent, upset the biological balance of the filter. Treatment plants with two or more filters can hasten the rebuilding of a "de-psychodied" filter by reseeding with the effluent from an operating filter.

Odors

When excessive odors predominate around a trickling filter it can be assumed that the filter is not operating at its most efficient rate. Trickling filters should be operated so that air circulates throughout the filter media. Foul odors do not accompany a completely aerobic process. One or more of the following conditions could be the cause of filter odors:

1. The influent sewage to the filter could be too strong.
2. An excessive quantity of solids could have been sent to the filter from the primary clarifiers. A foul slug of supernatant is frequently the cause of excess solids.
3. An excessive quantity of grease could be present in the raw sewage.
4. The filter underdrain system could be submerged, thus preventing the free circulation of air throughout the filter bed.
5. Faulty housekeeping could result

in the accumulation of moss, leaves, and sticks on the media surface, thereby collecting odor-causing solids.

Although remedies for these causes of odors are obvious, the following suggestions are often worth considering:

1. Recirculation to the filter will wash fine solids through the bed, dilute the influent sewage, and add dissolved oxygen.
2. Reduction of excessively long primary detention periods, especially in warm weather, will aid in maintaining a fresher sewage.

Ponding

A ponded trickling filter is generally caused by an excessive growth of filter slime that has clogged the spaces between the filter media. This excessive growth of slime is caused by loading the filter with a sewage very high in B.O.D. As stated previously, if filter fly larvae are present a ponding condition is extremely unusual.

One or more of the following procedures will often be effective in unclogging the average ponded filter:

1. Reduce the filter influent strength by recirculation.
2. Increase the hydraulic surface flushing rate by recirculation.
3. Flood the filter for one day.
4. Remove the filter from operation for 1 to 2 days so that the zoogleal masses will dry.
5. Chlorinate the filter influent every 4 to 7 days at a rate of 5 p.p.m. for periods lasting from 2 to 4 hr.
6. Stop the distributor over the ponded area.
7. Open the clogged section with a fire hose or by rodding.

Snails

Small brown snails may inhabit trickling filters, particularly in the milder climates. Their presence is of little concern in standard-rate filters or in high-rate filters where the recirculated flow has been settled prior to discharge to the filter. Some difficulty has been experienced in high-rate filters in which the snails were deposited in the mercury seal, thereby causing sufficient friction to stop the rotation of the distributor (THIS JOURNAL, **27**, 3, 377; Mar. 1955). Constant cleaning of the mercury seal and occasional flooding and flushing of the filter have been successful in controlling the snails.

Roaches

The presence of roaches at night around the walls of the filter is a good indication that the particular filter is roach-infested. Although it is true that as long as roaches remain within the filter no harm has been done, it is also true that the roach population could reach a sufficient number to cause a roach migration.

Flooding of the filter is effective in driving the roaches from the filter. The egress of the roaches must be met with an effective spray program using chlordane or some other insecticide (THIS JOURNAL, **25**, 9, 1104; Sept. 1953).

Moss

Trickling filters are occasionally infested with a fine green moss that grows over and betwen the filter media on the filter surface. Florida treatment plants have had a considerable problem in recent years due to this moss which, if uncontrolled, will eventually cover the entire surface of the filter, preventing normal filter operation. Scattered patches of moss create a partial ponding condition, with all the accompanying problems of insufficient air circulation, odors, and filter flies.

The following approaches to this problem have proven effective:

1. The affected filter can be removed from service for two to three weeks to dry out the moss, thus killing it.
2. The use of HTH powder (70 per

cent) is satisfactory for the treatment of scattered patches of moss. The filter should be removed from service for one day and all moss sprinkled with the powder. A one-day drying period should follow the application of HTH.

3. Super-chlorination can be used when the filter is loaded with moss and an extended drying-out period is not convenient. The filter is removed from service and drained for at least 4 hr.

At the end of this draining period chlorine is added to the influent at the dosing siphon at the maximum rate possible, or until a sufficient concentration is obtained to "burn" the moss. The distributor is rotated about 10 times or until the moss has been burned. The filter should remain idle two or more days before flushing and returning to service. Variations of this "burning" process have been used with success (THIS JOURNAL, **28**, 5, 691; May 1956).

Miscellaneous Operation Details

1. The distributor end gates should be opened daily or more often, if required. When this is done all clogged nozzles should be unplugged by pushing any solids through the nozzles into the arm with a small hand-rod. Any excess slime should be washed from the splash plates and away from the orifice at the same time, and clogged air release lines should be cleaned.

2. The filter underdrain system should be inspected frequently and cleaned by flushing. The underdrain system should be operated so that it flows only half-full during periods of normal flow.

3. The copper cowlings over ventilation shafts should always be in place. An operator who leaves the cowlings broken or the shafts open will soon find them to be the receptacle for filter media.

4. The orifice diameter of the distributor should not be enlarged without first obtaining the recommendations of the manufacturer. The hydraulic design of a trickling filter distributor is not simple.

5. The manufacturer's specifications for the filter distributor should be carefully studied and followed. Generally, the following routine is required:

(a) Paint the distributor annually using a quality product;
(b) Lubricate the top bearing monthly;
(c) Remove, clean, inspect, replace, and regrease the top bearing annually; and
(d) Drain the mercury from the seal every 6 months. Flush the chamber, clean with a caustic solution, and reflush. Clean the mercury by squeezing it through a clean cotton cloth. Weigh the mercury and add the amount needed to meet the specifications.

6. The guy-rod turn-buckles should be adjusted so that the distributor arms remain level in the winter and summer. This applies particularly to large diameter trickling filters.

7. Grease should be removed from the influent line to the trickling filter because it will reduce the pipe cross sectional area.

8. Heavy equipment should never be permitted on the surface of the filter media.

9. Unattended children should not be permitted around a sewage treatment plant.

Every operator of a trickling filter plant will readily admit his trickling filter is the dependable "work horse" in his plant. However, even a work horse, if provided with the proper care and attention, will be a better producer. Similarly, the operation of most trickling filters can be improved to some extent by giving them maximum care and attention.

INTERESTING EXTRACTS FROM OPERATION REPORTS

"It is never too soon to do a kindness, for one does not know how soon it may be too late."—*Smeltzer*

Attention operators! It will be appreciated if copies of all annual reports of both large and small sewage and industrial waste treatment plants are sent to the Federation office for abstracting in this section of the Journal. Please direct annual reports to: The Operator's Corner, Federation of Sewage and Industrial Wastes Associations, 4435 Wisconsin Ave., N.W., Washington 16, D. C.

Annual Report of the Detroit, Mich., Sewage Treatment Plant for the Fiscal Year, 1955 *

General

The Detroit sewage treatment plant serves the City of Detroit and 33 adjacent communities in the metropolitan area. Primary treatment is given to all dry weather flow. Settled sludge from the sedimentation tanks is disposed of by incineration after filtration. Approximately one-fourth of the sludge is pumped to a single digester which serves as a gas supply for heating purposes.

The total pumpage of 162,790 million gallons was an increase of 729 million gallons over the previous year and the greatest yearly total to date. This increase is attributed to completion of the Northwest interceptor and a rainfall increase of 3.36 in. during the year.

The bi-weekly practice of pumping the suction well sewage level 10 ft. below normal to create scouring velocities in the interceptors was continued. The suction well was inspected daily and large floating objects, such as tree branches and construction timbers, which may have been carried by the flow in the two interceptors (12 ft. 9 in. and 16 ft. in diameter), were removed to prevent possible damage to the unprotected pumps. In August and September a higher velocity was maintained in the interceptors to accommodate the waste from air-conditioning equipment.

The weekly survey of the Detroit and lower Rouge rivers was continued as in previous years. Other survey and inspection trips aided in maintaining a check on river and lake conditions. Interceptor regulators, backwater gates, and dams were inspected periodically to insure proper flow to the Detroit River.

Both the East and West ash lagoons were emptied of 120,891 cu. yd. of ash. This was the first time both lagoons were emptied in the same fiscal year. Lagoon dikes had to be moved to permit the construction of influent conduits to the new sedimentation tanks.

Plant Expansion

The Northwest interceptor, a 10-ft. diameter, concrete-segment conduit under construction for the past two years, was completed and connected to the Southfield district and Middle Rouge area sewers in May 1955. This interceptor was estimated to add 65 m.g.d. to the plant influent.

To treat the additional sewage, plant enlargements and equipment additions were undertaken. Two 230-c.f.s. main sewage pumps, additional bar racks and grit collector equipment, two sedimentation tanks, and four 500-sq. ft. rotary vacuum filters were either under construction or installed.

* For last previous extract see THIS JOURNAL, **27**, 9, 1093 (Sept. 1955).

Solids Removal

The bar racks and grit chamber collectors functioned satisfactorily. Screenings collected on the bar racks were ground and returned directly to the sewage influent without weighing. Pieces of metal, rags, wood and other debris were removed manually from the conveyer and hauled to a dump. Considerable amounts of paper containers, tin cans, and garbage were removed by the racks, indicating the continued disposal of raw garbage and trash to the sewer system.

Grit removal increased 2.18 per cent to a total of 18,632 tons (wet basis). This was the greatest quantity of grit to be removed to date.

Grease and scum removal decreased 21.02 per cent from the previous year to 1,946 tons. This was the first time the quantity of grease and scum decreased when the sewage flow increased.

The individual sedimentation tanks were out of service only for inspection or replacement of worn and broken parts. The original 25-lb. rail embedded in the concrete bottom of No. 3 tank, for the support of the sludge collector flights, had worn below the concrete and was built up by spot-welding strip steel to the rail.

The practice of stopping the main sludge collectors during and after storm flows was continued and overloads did not occur. Storm flows cause a heavy deposition of grit and low volatile sludge which is undesirable as digester feed. Piping from No. 6 tank made it possible to pump directly from this tank to the digester. During storm flows the inlets to this sedimentation tank were closed and the digester fed with the sludge already accumulated in the tank. Expected advantages were not definitely proven, but the test will be continued.

Digestion

The digester loading was reduced and gas production decreased below normal due to poor heat exchange. On May 25 the tank was dewatered for the bi-annual inspection, cleaning, and de-scaling of the heating coil. Service was restored on June 4.

Digester contents could not be pumped to the low area at the rear of the plant site as formerly, since this area is the site of new sedimentation tanks. The sludge was withdrawn to the plant influent and no difficulty was experienced in the grit chambers or sedimentation tanks. A large volume of scum and oil was skimmed from the tanks and burned satisfactorily on the lower hearths of one of the incinerators.

The sludge-gas engine generator was operated only when there was digester gas in excess of the requirements of the heating system boilers. The boilers were supplemented with fuel oil during heavy loads. One 200 h.p.-boiler was usually adequate for the winter heating load.

The newest type combustible-gas analyzer alarm was installed for added protection.

Sludge Filtration

Sewage solids conditioned and filtered totaled 62,151 tons (dry basis), an increase of 13.37 per cent compared with the previous year. Of the total, 88.66 per cent was conditioned with ferric chloride and lime, and 11.34 per cent with lime only. The increased use of ferric chloride as a conditioning agent was again evident due to changes in the characteristics of the settled sludge.

A waste slurry from acetylene production continued as the main source of lime; pebble lime was used only when insufficient quantities of slurry were obtainable.

The nylon filter cloth was used again on "summer" sludge for 450 hr. The same "blinding" occurred after each 200 hr. of operation, and required washing with a 10 per cent solution of muriatic acid. The texture

of the cloth appeared sound after a total operating time of 1,584 hr. An experimental 10-oz., all-wool felt filter cloth blinded badly and tore after 119 hr. of use.

Sludge Incineration

Operation of the three incinerators was satisfactory at an average feed rate of 8.26 tons per hour. The quantity of sludge incinerated increased in direct proportion to the quantity filtered.

An unusually heavy rainfall in October (7.8 in.) brought a black dirt to the plant which would not support combustion. Additional fuel oil was necessary for incineration. This required 138 gal. per ton (wet basis), an increase of .013 gal. per ton.

Chlorination

Chlorination continued on the basis of determining the chlorine demand of the sedimentation tank effluent rather than the influent. Demands were low, averaging 4.71 p.p.m. Dosage was maintained at 80 per cent of demand during most of the year. It was reduced to 60 per cent from December 16 to January 5, but rising effluent counts made it necessary to resume 80 per cent application. During the summer, dosage was at 100 per cent of demand. Approximately 96.4 per cent of the coliform bacteria were killed.

An alarm system was installed in the chlorinator building which would give adequate warning of the following:

1. Excessive pressure in chlorine tanks or piping.
2. Excessive or inadequate temperatures in the chlorine evaporator.
3. Failure of the hot-water circulating pumps.

TABLE I.—Summary of Operating Data at Detroit, Mich., for the Fiscal Year, 1955

Item	1955
Rainfall, total (in.)	28.7
Estimated connected pop.	3,000,000
Sewage pumped (m.g.d.)	446
Solids removed:	
Grit, dry (tons)	9,802
Tank scum (tons):	
Dry	1,266
Volatile	1,138
Susp. solids (tons):	
Dry	60,888
Volatile	39,029
Total solids (tons):	
Dry	71,956
Volatile	43,418
Analytical data:	
Susp. solids:	
Influent (p.p.m.)	203
Effluent (p.p.m.)	115
Reduction (%)	43.5
B.O.D.:	
Influent (p.p.m.)	130.9
Effluent (p.p.m.)	90.6
Reduction (%)	30.8
Grit (%):	
Solids	52.6
Volatile	33.2
Raw sludge to digester (%):	
Total solids	10.6
Volatile solids	58
Sludge digestion:	
Total added (m.g.)	22.6
Dry solids added (tons)	10,202
Dry solids withdrawn (tons)	7,995
Supernatant (%):	
Solids	8
Volatile solids	50.4
Gas production:	
1,000 cu. ft.	75,388
Cu. ft. per vol. sol. added	6.43
Sludge filtered:	
Total (m.g.)	129
Dry solids (tons)	62.1
Solids (%)	11.2
Volatile solids (%)	56.4
Filter yield (lb./sq. ft./hr.)*	3.9–4.4
Sludge cake, filtered (%):	
Solids	35.1
Volatile	53
Incineration:	
Wet (tons)	217,322
Dry (tons)	80,227
Wet feed rate (tons/hr./incin.)	8.3
Fuel oil per wet ton burned (gal.)	0.139
Chlorination (p.p.m.):	
Demand	4.71
Applied	3.65

* Depending on conditioning chemicals used.

TABLE II.—Summary of Operating Expenses, Detroit, Mich., 1955

Item	Fiscal Year Ended June 30, 1955
General plant	$ 188,159.92
Pumping stations	253,409.39
Bar rack and grit removal	60,179.63
Sedimentation	82,820.96
Chlorination	201,610.43
Digestion	12,575.53
Filtration and chemicals	192,701.46
Incineration and ash handling	378,249.04
Boiler plant	51,679.69
Dearborn sewage treatment	124,917.95
Interceptors	30,164.94
Sanitary sewage pump station	263,881.40
Miscellaneous	101,100.11
Administration	103,873.99
Depreciation	527,955.59
Total	$2,573,280.03

Control and Research

The laboratory ran upwards of 400 chemical, physical, and bacteriological tests daily in the performance of routine control tests. Among the important functions were: (a) chlorination control, (b) sludge filtration control, (c) analysis of all chemicals received, (d) boiler control, (e) digester gas analysis and odorant metering control, (f) first aid, (g) lubricating oil quality control, (h) river survey sampling and testing, and (i) periodic inspection of drinking water fountains throughout the plant.

In addition, several fly-ash samples were collected and analyzed and a 100-day performance test was run on a number of rubber and plastic paints.

Miscellaneous

All personnel were given the annual opportunity of having a chest X-ray. Yearly typhoid inoculations were offered to all employees. A 50 per cent participation in this preventive medicine program was observed when 93 employees availed themselves of the opportunity. There have been no recorded cases of typhoid or paratyphoid among employees.

Table I summarizes the 1955 operation data and Table II summarizes the operating expenses for the same period.

PARTS INVENTORY CONTROL *

Effective stockroom control speeds maintenance work and insures that no "red-face" shortage develops. Sewage treatment plant and pumping station operation is on a round-the-clock, seven-day-week basis. To keep equipment running, adequate stocks of spare parts, materials, lubricants, miscellaneous equipment items, and hand tools must be kept available. In addition, a working system of paperwork control must be maintained. Adequate control is essential to locate the items quickly and avoid stock shortages.

A standard card index system is in operation at the Little Miami Sewage Disposal Works, Cincinnati, Ohio. It serves as a "locator" file and provides close control of inventories.

Each part or item in stock is cross-indexed on two file cards which are enclosed in a file pocket. One card serves as an inventory record and is kept in the bottom half of the pocket. The other card, kept in the top pocket, carries a complete description of the part and a cost record.

The card in the bottom pocket has the part name and a brief description printed on the bottom line. This line is visible through folded acetate when the file is in the closed position, which makes it possible to locate the card quickly. The card carries information on the location of the item in the storeroom, and the maximum and minimum number of that particular item to be kept on hand.

* Courtesy, Sewage Disposal Section, Cincinnati, Ohio.

When the quantity of any item in stock is less than the established minimum number, the storekeeper fills in a requisition for replacement. The quantity of material requisitioned and the date of the requisition are entered on the card.

When the ordered material has been received, the date of receipt, purchase order number and cost are entered on the card in the top pocket. In addition to a complete description of the item, this card lists detailed specifications, the firm from whom purchased, the purchase order number, quantity and date of purchase, and the unit cost.

An inventory of all material in the stockroom is made once each year. This serves as a check on the completeness of the paper work, and assures that the card-file system functions as intended. The inventory count is marked in red on the top-pocket card, balances are corrected as necessary, and the final quantity is marked in red on the bottom-pocket card.

TIPS AND QUIPS

Quarter Century Operators' Club

During 1956 six new members were added to the active membership roll of the Quarter Century Operators' Club, although the passing of Frank Woodbury Jones and Russell Smith brought a note of sadness to all.

Newly qualified members approved by the Federation Board of Control on October 7, 1956 are:

Philip Artese, Red Bank, N. J.
John W. Collom, Bordentown, N. J.
Joel C. Dullard, Atlanta, Ga.
M. S. Fitzsimmons, Lincoln, Nebr.
Ralph E. Fuhrman, Washington, D. C.
Herbert W. Hansen, Ravenna, Ohio

The roster in October included 54 living and 12 deceased members.

To be eligible for membership in the Quarter Century Operators' Club the candidate must have been in full-time resident charge of the operation of a sewage treatment plant 25 years prior to the date of his admission to the Club.

During the year a roster of all Club members was prepared and mailed to the members by the chairman. To facilitate the preparation of membership certificates, the names of new members will be submitted to the Federation Board of Control only during the annual meeting each year.

All eligible personnel are urged to contact the chairman of the Club: Henry Van Der Vliet, P. O. Box 281, Rutherford, N. J.

Help the New Employee

A new employee should certainly be shown—

. . . the way about the plant.
. . . the way to get acquainted with the people he ought to know.
. . . the way to do his work most easily and safely.

Treat the new employee as you wanted to be treated when **you** were a green hand.

Cincinnati, Ohio

The "nerve center" of Cincinnati's Metropolitan Sewage Disposal Program has moved to its new administration building at the Mill Creek sewage works. The two-story and basement, air-conditioned building provides 21,000 sq. ft. to house administrative offices, engineering, accounting, and sewage plant and industrial waste laboratories. Glass block replaces win-

dow glass in the second-floor laboratories.

In addition to offices and laboratories, a meeting room, kitchen, store rooms, garage and other facilities are provided.

Good Sewer Construction Practice

Proper procedures to insure good sewer construction are clearly illustrated in a four-page bulletin entitled "Good Practice in Sewer Construction." Complete information on proper techniques for trench preparation, inspection, back filling (including trench widths and depths), and bedding is included.

Copies can be obtained from the Clay Sewer Pipe Association, 311 High-Long Building, 5 East Long St., Columbus 15, Ohio.

TWSWA Officers

Officers of the recently organized State Auxiliary of the Texas Water and Sewage Works Association are:

President: Mrs. Sid L. Allison, Corpus Christi.

Vice-President: Mrs. W. S. Mahlie, Fort Worth.

Secretary-Treasurer: Mrs. LeRoy N. Rice, Jr., Harlingen.

Mrs. Rice is also the current editor of the quarterly journal-in-miniature, "The Pipette," and will welcome correspondence. The mailing address is P. O. Box 469, Harlingen, Texas.

Oil Squirter

A handy time-saving, portable hand pump is now available for use directly on a gallon oil can or other large container. The suction hose of the pump can be tapped directly to the large oil container. The pump itself is easy to manipulate and has a sturdy oil-can type pouring spout. The unit is recommended for easy filling of all types of oil cups and reservoirs without the need for constant refilling of small oil cans.

Information on the "Redi-Pump" may be obtained from the Trico Fuse Manufacturing Co., 2948 N. 5th St., Milwaukee 12, Wisconsin.

Safety is a personal responsibility.

Ladder Maintenance *

Care of ladders is an important safety factor. Here are some good maintenance suggestions:

1. Inspect ladders at frequent regular intervals; if any ladder is found defective, either repair or discard it.
2. Use shellac, varnish, or two coats of oil as a preservative; paint conceals defects.
3. Keep ladders clean.
4. Do not lay ladders on wet ground, or leave them exposed to the weather. Ladders lying on the floor may cause workers to trip and fall; or they may be run over by trucks and damaged.
5. If ladders with metal parts are exposed to acid fumes, inspect these parts frequently.
6. Roughen metal ladder rungs to prevent slipping.
7. Never leave a ladder where it may fall.
8. Store ladders in a cool dry place, either lying on their sides or hanging by their rails from several wall brackets in a horizontal position. Take care, however, that these suspended ladders do not warp.

$71

Cincinnati's present sewage treatment program is being undertaken at a cost of $71 per person based on 1956 population served.

* National Safety Council, Safety Instruction Card No. 340.

Student!

Officials of a Pennsylvania borough were somewhat perturbed when the sewage treatment plant went on the blink for the second time within two months and the plant operator could not be reached. He was attending a course on how to operate sewage plants.

More on Sewage Sterilization

The Army Chemical Corps is sponsoring a project on the use of ionizing radiation as a possible method of sterilization of sewage. This research project, another in the continuing search for ways to apply developments of the Atomic Age to sewage treatment, is under study at Armour Research Foundation of the Illinois Institute of Technology, Chicago, Ill.

Sightless

In the United States more than 80,000 persons, it has been estimated, have lost the sight of one eye as a result of industrial hazards and nearly 8,000 have lost the sight of both eyes. Vision is as important as the specialized tools an employee may use, yet it cannot be replaced if destroyed.

Sewer Explosion

Explosion and fire unexpectedly caught three Cincinnati Highway maintenance men while clearing a clogged interceptor sewer. Two men were working in the manhole, with the third man at the top of the manhole. Suddenly there was a flash followed by a loud explosion and flames shot from the manhole, burning the three men severely.

The Cincinnati Sewage Disposal Section immediately responded in an effort to determine the materials responsible for the explosion. A mobile laboratory arrived on the scene within 45 min., and explosion meter readings and gas samples were taken. Meter readings were less than 25 per cent. The gas samples were processed through the spectrophotometer in the industrial waste laboratory, but failed to show an identifiable gas. A carbon monitor, composed of activated carbon in a sample bag, was exposed in the manhole for two days. Analysis showed only a trace of a short-chain alcohol, such as ethyl or propyl alcohol.

In an effort to identify the explosive material the Sewage Disposal Section installed monitors in the sewers in the area of the explosion. These will be processed regularly in an effort to identify correctly the explosive substance. If such identification is possible it will be turned over to the Industrial Waste Unit for detective work in locating the company using the substance.

Through the efforts of a well-organized and equipped industrial waste laboratory, control of volatile material discharged to the Cincinnati sewer system has been very successful.

Ion Exchange Decontamination of Water-Borne Radioactivity

Drinking water contaminated by radioactive fallout, or by improper disposal of atomic wastes, could be made safe for emergency drinking by the use of mixed-bed ion exchange resins. However, initial beta-gamma activity concentrated in the water must not be greater than the tolerance value by more than a factor of 10. For practical purposes, 15 to 30 min. may be considered as sufficient contact time.

Research work has been undertaken by the Engineer Research and Development Laboratories, U. S. Corps of Engineers.

You'll never stumble on anything good while sitting down.

Federation Affairs

TWENTY-NINTH ANNUAL MEETING REPORT

The 29th Annual Meeting of the Federation, held at the Hotel Statler in Los Angeles, California, marked the third time in Federation history that an Annual Meeting was held west of the Mississippi River; the first time was a joint meeting with the American Water Works Association in San Francisco, California, in 1947, and the second was at St. Paul, Minnesota, in 1951. The total registration was 1,030, the fourth highest in the history of these meetings. The men's total was 788, and the ladies' total was the second highest on record, with 242 ladies registered. Geographically, members or guests were registered from 39 states, the District of Columbia, Canada, England, Germany, Hawaii, Puerto Rico, and Sweden. Member Associations were well represented, with members from all except two of the Member Associations in the United States. Top-placing Member Associations, attendance-wise, were California, Central States, New York, New Jersey, Pennsylvania, and Michigan, in decreasing order of registered members.

The success of the meeting in all its phases is due in large measure to the efforts of the host California Sewage and Industrial Wastes Association, as represented by the Local Arrangements Committee headed by Arthur G. Pickett. The planning of details and the cooperative efforts by the various committees aided in making a highly satisfactory and enjoyable meeting. Los Angeles weather was practically smog-free and the delegates will long remember a most pleasant experience.

The 29th Annual Meeting was convened at 10:15 AM on Monday, October 8, 1956, by President George W. Martin. Following the invocation by Mr. Ray W. Ragsdale and the official welcome by Admiral Cushing Phillips, President Martin greeted the attendants and commented briefly on Federation activities during the past year. The report of Executive Secretary-Editor, Ralph E. Fuhrman, concluded the business portion of the opening session.

Technical Program

Topics of broad general interest, as well as many papers on specific waste treatment problems, characterized the technical program developed by the Program Committee under the chairmanship of Professor Rolf Eliassen. The regular Operator's Forum and the Industrial Wastes Forum featured selected papers on plant operation and industrial wastes problems. The presentation of the Research Forum for the second time in as many years was well received, indicating an increasing interest in this important facet of Federation program activity.

Two new program features which drew excellent attendance and much lively and pointed discussion were the Sewer Maintenance Forum, and the Water Pollution Control Symposium. Sewer maintenance forums have been featured regularly at California Association meetings, and the comment and attendance spoke well for its inclusion in future Federation programs. The comments heard at the Water Pollution Control Symposium, at which Mark Hollis, Chief Engineer, USPHS,

answered queries on Public Law 660 from state and sanitary engineers and others, were well received. In 1955 this symposium was held as an extracurricular event at the Atlantic City meeting. However, it was considered of such value by those in attendance that it was made a part of the 1956 program.

An interesting program and discussion was presented at the Laboratory Scientists' Breakfast for a small select group of sewage treatment plant professionals.

The technical program was as announced in the "29th Annual Meeting Preview" (see THIS JOURNAL, **28**, 9, 1190; Sept. 1956). Technical program papers are to be published in the 1957 issues of the Journal, beginning with this issue.

Highlight papers of the program included several papers on various phases of the Los Angeles Hyperion sewage treatment plant program.

Entertainment Events

Entertainment of such excellence that it will long be remembered by Federation attendees was presented at the Family Night program on Monday evening. Both entertaining and educational, the Hilo Hattie Hawaiian show was ideal fare for the family. The program featured songs and customs of the Hawaiian Islands as presented by native Polynesians, and was presided over by Hilo Hattie, well-known Hawaiian. To climax the enjoyment of the evening a delicious Hawaiian punch was served to the guests during intermission.

The meeting broke with tradition in that no annual Federation Luncheon was featured. Although a luncheon was tentatively planned at the time of the September Convention Preview, circumstances prevented its final scheduling.

The Annual Federation Awards Dinner, held in the Pacific Ballroom on Wednesday evening, October 10, was particularly well received. A sell-out attendance of almost 800 members and guests gathered to dine and witness the presentation of the annual Federation awards. New Federation officers were introduced to the group. Dancing followed to complete the enjoyable evening.

Ladies' Entertainment

The entertainment features planned for the ladies by the local Ladies Entertainment Committee kept the ladies well occupied.

Monday afternoon a hospitality hour provided an opportunity to renew old acquaintances and make new friends.

Advantage was taken of the many opportunities for sightseeing and shopping in the fabulous Los Angeles metropolitan area. Attendance at all events was good and a near-record number of women were registered.

Inspection Trips

The planned inspection trips catered to the interests of both sewage works and industrial wastes members. The programmed inspection trip to the Los Angeles Hyperion activated sludge sewage treatment plant was well attended. The inspection was conducted smoothly and to the satisfaction of all who viewed this large and impressive facility.

The Inspection Trip Committee provided daily trips to industrial waste treatment facilities in the Los Angeles area. Approximately 200 convention visitors took advantage of the scheduled trips. The largest group numbered about 40 and visited the Watson Refinery of the Richfield Oil Company.

Manufacturers' Exhibit

New equipment, products, and process developments were displayed as a co-feature of the Los Angeles meeting. The exhibits were arranged by the Water and Sewage Works Manufacturers' Association, and occupied 79

booths, which were located in an area convenient to the technical sessions. All alloted space was fully utilized by the various manufacturers.

BOARD OF CONTROL MEETS AT LOS ANGELES

The 29th Annual Meeting of the Federation Board of Control at Los Angeles, Calif., concluded another year of continuing membership growth of the Federation Member Associations. During the preceding 12 months the relatively new Federation headquarters staff was becoming seasoned and the publication schedule of the Journal was much improved.

Most noteworthy of the actions taken by the Board of Control was the approval, with certain recommendations, of revisions in the Federation Constitution and Bylaws. Particular changes were:

1. Provision for the appointment of one additional Director by each Member Association which has maintained a total Active plus Corporate membership of 500 or more during the preceding three years. Directors must be members in good standing of their respective Member Associations.

2. More specific designation of proxies to the Board of Control.

3. Limitation of the terms of Federation Constitutional Committee chairmen to five years. These chairmen may no longer vote on Board of Control matters, although they are expected to attend meetings of the Board with full privilege of discussion.

4. Creation of a General Policy Committee to recommend general or long-term policies of the Federation.

5. Change in the name of the "Publications Committee" to "Publications and Program Committee."

Other actions of the Board included the following:

1. Approved publication in the Journal of the "Units of Expression" as a tentatively recommended report, to obtain the benefit of comments by the Federation membership.

2. Accepted the recommendation of the recently appointed (1954) Safety Committee for increased Federation activity in the field of employee safety.

3. Instructed that Bedell and Hatfield award nominees must be members of Member Associations or the affiliated section in the case of water and sewage groups.

4. Authorized work on the revision of the safety and sewer ordinance manuals, M. O. P. Nos. 1 and 3, respectively.

5. Authorized the expenditure of funds for the publication of the sewer maintenance manual and the manuals being prepared jointly with the American Society of Civil Engineers on storm and sanitary sewer design, and sewage treatment plant design.

6. Approved certain constitution changes of the Pennsylvania, Georgia, Florida, Kansas and New England Member Associations. Authorized a complete study of the membership practices of the Member Associations by a special committee.

For the meeting of the 1956 Board on October 7, 41 officers and directors answered roll call. Roll call for the October 11 organization meeting of the 1957 Board indicated 41 in attendance.

New Officers

The following officers were elected on October 7 for the terms indicated:

President: Emil C. Jensen, Seattle, Wash., to October 1957.
Vice-President: Kenneth S. Watson, Schenectady, N. Y., to October 1957.
Treasurer: W. W. DeBerard, Chicago, Ill., to October 1957.
Director-at-Large: W. W. Gillespie, Jacksonville, Fla., to October 1959.

Experience outlines for the new President and Vice-President are given elsewhere in this issue.

1956 Awards

The following honors and awards, as conferred by the Board, were presented or announced by President Martin at the Annual Awards Dinner on October 10:

Elected to Honorary Membership was William Homer Wisely of New York, N. Y., former Executive Secretary-Editor of the Federation and now Executive Secretary of the American Society of Civil Engineers.

The Harrison Prescott Eddy Medal was earned by George J. Schroepfer, W. J. Fullen, A Stanford Johnson, Norman R. Ziemke and James J. Anderson for their research work at the University of Minnesota, as presented in their paper "The Anaerobic Contact Process as Applied to Packinghouse Wastes" (THIS JOURNAL, **27**, 4, 460; April 1955).

The George Bradley Gascoigne Medal was conferred on Henry R. King of the Sanitary District of Chicago, for his plant-operation contributions entitled "Mechanics of Oxygen Absorption in Spiral Flow Aeration Tanks" (THIS JOURNAL, **27**, 8, 894; **27**, 9, 1007; and **27**, 10, 1123; Aug., Sept., and Oct. 1955).

The Industrial Wastes Medal was awarded to Charles R. Griffith of the Dana Corporation, Fort Wayne, Ind., for his contribution "Lagoons for Treating Metalworking Wastes (THIS JOURNAL, **27**, 2, 180; Feb. 1955).

For his numerous scientific contributions to the technical literature, and his factual approach to the art and science of sewage treatment, as evidenced by his interest in the problems of operation as well as in the new developments of process and design, and for his outstanding record of personal service to the profession and the Federation, E. Sherman Chase was awarded the 1956 Charles Alvin Emerson Medal.

Nominations for the 1956 Arthur Sidney Bedell Awards, for service to Member Associations of the Federation, were confirmed by the Board as follows: Arthur G. Pickett (California); Ray J. Desmarais (Canadian Institute); W. W. Mathews (Central States); John E. Kiker, Jr. (Florida); Charles Egerton Drummond, Jr. (Georgia); W. McLean Bingley (Maryland-Delaware); Rodney Preator (Montana); Steven M. Hurley, Jr. (New England); Earl Devendorf (New York); Bruce Magaw McDill (Ohio); William J. Bishop (Oklahoma); C. H. Young (Pennsylvania); Luis Ramos Robles (Puerto Rico); Richard Messer (Virginia); and Harry Kenneth Gidley (West Virginia).

Nominations for the 1956 William D. Hatfield Awards, for outstanding sewage treatment plant operation, were confirmed by the Board as follows: Murray B. McKinnie (California); I. G. Knoebel (Central States); Robert E. Simon (Florida); C. Gordon Remsburg (Maryland-Delaware); Frederick W. Crane (New York); Arthur D. Caster (Ohio); Curtis L. Glenn (Oklahoma); Robert Bolenius (Pennsylvania); and A. F. Chamblin (Virginia). This was the first year in which the Hatfield Awards were presented under the new schedule approved in 1955 (THIS JOURNAL, **27**, 1, 118; Jan. 1956). Several Member Associations, who were eligible to nominate an awardee, chose to decline the award pending perfection of their system of candidate selection.

Membership

The Secretary reported that the aggregate Active and Corporate membership of the 38 associations comprising the Federation was at a record high of 6,986 on September 30, 1956, a gain of 4.4 per cent for the year. While many Member Associations made excellent gains, losses by others limited

total growth to 293. Increased membership was recorded by 26 Member Associations, while 12 recorded no increase or a loss.

The total number of Associate Members increased to 75 on September 30, 1956.

The Kentucky-Tennessee association placed first in both the numerical and percentage increase contests with 60 new members, for a 50 per cent increase. When the same Member Association attains both the highest percentage and numerical increase, the contest rules give the second award to the association recording the second highest numerical gain; the Central States Association, with a 40-member increase, received this award.

California (36) was a close contender for the numerical increase prize, and the Institution of Public Health Engineers (41) and Alabama (29) were runners-up for the percentage increase prize.

Financial

The operating budget for fiscal 1957 is balanced at $121,800, an increase of $9,550 over the previous year, and represents a continued rise in the operational costs of the Federation.

Audited net worth of the Federation at the end of 1955 was $81,393.50; once again a modest increase is indicated for the year 1956.

Milwaukee in 1961

At the 1956 Board meeting, approval was given to meeting places for the years 1958 through 1960. The 1957 Board directed the Meeting Place Committee to give further study to the 1961 meeting place for which the Committee recommended Milwaukee, Wis. (After further study, the new Meeting Place Committee again recommended Milwaukee and by mail ballot in November, the Board of Control approved this recommendation.) Previously announced meeting sites already approved were:

1957, Boston, Mass., Hotel Statler, Oct. 7–10.
1958, Detroit, Mich., Sheraton-Cadillac Hotel, Oct. 5–9.
1959, Dallas, Texas, Hotel Statler-Hilton, Oct. 11–15.
1960, Philadelphia, Pa., Philadelphia-Sheraton, Oct. 2–6.

New invitations received verbally from the Iowa Sewage and Industrial Wastes Association (Des Moines), the Kansas Sewage and Industrial Wastes Association (Kansas City, Mo.), the Nebraska Sewage and Industrial Wastes Association (Omaha), and the New York Sewage and Industrial Wastes Association (New York City), were referred to the Meeting Place Committee. Invitations from Member Associations were already on hand from: Canadian Institute (Toronto), Florida (Miami Beach), Georgia (Atlanta), Missouri (Kansas City, Mo.), Pacific Northwest (Portland or Seattle), Rocky Mountain (Denver), and Verband Schweizerischer Abwasserfachleute (Swiss).

SCHEDULE OF BEDELL AND HATFIELD AWARD NOMINATIONS

The Federation Board of Control approved the accompanying schedule of Bedell and Hatfield Award nominations on October 7, 1956. Each Member Association is eligible to nominate a recipient of each award in accord with the published rules governing the frequency of awards to be made (THIS JOURNAL, **27**, 1, 116 and **28**, 1, 118; Jan. 1955 and Jan. 1956). A Member Association may elect to by-pass the nomination of a recipient of one or

both awards. A by-passed award, however, is lost and cannot be given at a later date.

The schedule of awards for each current three-year period will be published annually in the January issue of the JOURNAL.

Bedell and Hatfield Award Schedule*

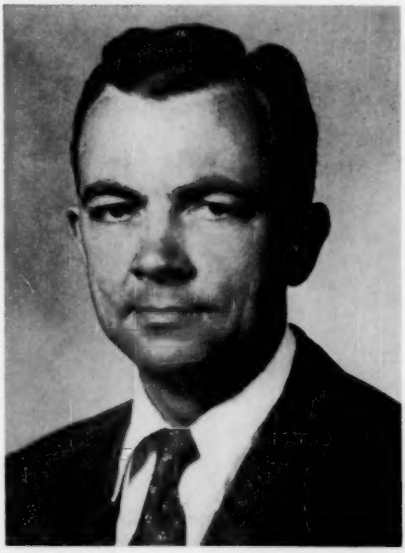
Member Association	Members	Nominations per 3 Years	Future Schedule			Member Association	Members	Nominations per 3 Years	Future Schedule		
			1957	1958	1959				1957	1958	1959
Alabama	45	1	1	—	—	Missouri	55	1	1	—	—
Arizona	40	1	1	—	—	Montana	37	1	—	—	1
Arkansas	58	1	—	—	1	Nebraska	74	1	—	1	—
California	611	3	1	1	1	New England	390	2	1	—	1
Canadian Institute	472	2	1	—	1	New Jersey	255	2	1	1	—
Central States	693	3	1	1	1	New York	621	3	1	1	1
Dakota (North & South)	37	1	—	—	1	North Carolina	159	1	—	1	—
Federal	76	1	—	1	—	Ohio	376	2	1	—	1
Florida	255	2	1	1	—	Oklahoma	55	1	—	—	1
Georgia	103	1	—	—	1	Pacific Northwest	311	2	1	1	—
Germany	38	1	1	—	—	Pennsylvania	503	3	1	1	1
Iowa	122	1	—	1	—	Puerto Rico	43	1	—	—	1
IPHE (England)	38	1	1	—	—	Rocky Mountain	58	1	—	—	1
ISP (England)	134	1	—	1	—	South Carolina	47	1	—	1	—
Kansas	110	1	1	—	—	Sweden	91	1	—	1	—
Kentucky—Tennessee	180	1	—	1	—	Swiss	15	1†	1†	—	—
Louisiana	15	1†	—	1†	—	Texas	198	1	—	1	—
Maryland—Delaware	70	1	—	—	1	Virginia	125	1	—	—	1
Michigan	396	2	1	1	—	West Virginia	80	1	—	—	1
						Total	6,986	—	18	18	17

* Schedules for 1958 and 1959 based on membership as of Sept. 30, 1956.

† Year eligible to petition for one nomination.

EMIL C. JENSEN NEW PRESIDENT

Emil C. Jensen, Chief of the Division of Engineering and Sanitation, Department of Health, State of Washington, became the 17th President of the Federation at the organization meeting of the 1957 Board of Control, held at Los Angeles, California, on October 11, 1956.



After graduation from the University of Washington in 1936 with the degree of Bachelor of Science in Civil Engineering, Mr. Jensen was employed as a stress analyst with the Boeing Airplane Company. He accepted a Gordon McKay Scholarship for a year of graduate study at Harvard University and received a Master of Science degree in Engineering in 1938. From 1938 through 1941 he served the Yakima County Health Department in Washington as a sanitary engineer. In 1941 he became a district sanitary engineer for the Washington State Department of Health and continued in this capacity until 1945, when he assumed his present position.

Mr. Jensen is a Registered Professional Civil and Sanitary Engineer

and holds a reserve commission as sanitary engineer (Lt. Comdr.) in the U. S. Public Health Service. He is a Fellow of the American Public Health Association and a member of the American Water Works Association, the Conference of State Sanitary Engineers, the National Association of Sanitarians, the Engineers Club of Seattle, and Sigma Xi and Tau Beta Pi, scholastic honoraries. He is a member of the American Society of Civil Engineers, was president of its Spokane Section in 1944 and of its Seattle Section in 1955, and is active in the Sanitary Engineering Division of the Society.

In addition to his regular duties, Mr. Jensen has contributed generously to his profession through his active interest in the Federation and in many professional engineering societies. He served the Pacific Northwest Sewage and Industrial Wastes Association as President in 1952, and as National Director, 1953–56, receiving the Federation's Bedell Award in 1955. He was instrumental in establishing a program for voluntary certification of sewage works operators under the administration of the Pacific Northwest Association.

Mr. Jensen completed the unexpired term of John W. Cunningham, Vice-President (1955–56). He has been a member of the Executive and Meeting Place Committees of the Federation. At present he is a member of the Executive, Finance, Joint Policy, General Policy, Meeting Place, and Honorary Membership Committees.

A native of Washington state, Mr. Jensen is married and has three children. He is an enthusiastic sportsman and includes hunting, fishing and skiing among his hobbies.

KENNETH S. WATSON ELECTED VICE–PRESIDENT

Kenneth S. Watson, Consultant, Water Management and Waste Control for the General Electric Company, Schenectady, N. Y., was elected to the Vice-Presidency of the Federation at the Election Committee meeting on October 7, 1956.

As a specialist on industrial waste treatment and water conservation, he brings to his Federation office a particularly good insight into the problems confronting the industrial waste field. His professional competency makes him a well qualified representative of the industrial waste facet of the Federation family.

Prior to the acceptance of his present position, Mr. Watson was Assistant Director with the Ohio River Valley Water Sanitation Commission. A graduate of West Virginia University with Bachelor of Science and Master of Science degrees in Chemical Engineering with sanitary options, he served as chemical engineer and later as Executive Secretary-Engineer of the West Virginia Water Commission.

His interest in water pollution control was manifested by his membership on the Interstate Commission on the

Potomac River, prior to associating with the General Electric Company. He also was a member from West Virginia on the Ohio River Valley Sanitation Commission.

Mr. Watson is a member and past-chairman of the National Technical Task Committee on Industrial Wastes, and is a member of the American Water Works Association, the American Institute of Chemical Engineers, the American Chemical Society, and the Manufacturing Chemists' Association Water Pollution Abatement Committee. He is a Professional Engineer and a Lt. Colonel in the U. S. Army Reserve Corp.

In May 1956 he was designated by the Secretary of State to serve as engineer-adviser to the United States delegation to the World Health Assembly meeting in Geneva, Switzerland.

He has written extensively on water management and waste treatment, having published more than 30 papers in this field. In 1955 he received the Federation's Industrial Wastes Medal.

Federation affairs have engaged Mr. Watson's interest for a number of years. At present he is a member of the Executive Committee of the New York Sewage and Industrial Wastes Association and was West Virginia Director on the Federation Board of Control (1948–50). He is Vice-Chairman of the Industrial Wastes Committee and a member of the Executive and the Meeting Place Committees.

Editorial

THE JOURNAL'S NEW COVER

As you opened this issue of the Journal, you probably observed the new paper stock used in the cover. The Journal is scheduled to appear in this new dress for an indefinite period.

The change from the traditional blue paper cover has been made only after long investigation and study of cover possibilities. For over a year these possibilities have been under consideration and it was only after a most thorough consideration of the pros and cons that the matter was referred to the Federation Board of Control at its Los Angeles meeting. Without hesitation, the Board concurred in the recommendation to make the change.

The former ripple-finish cover stock had the advantage of being durable and suited to the general conditions of service to which a journal cover is exposed. It had the serious disadvantage of inferior reproduction of some advertising material, particularly photographs. As modern advertising is using halftones more and more, the pleas of advertisers could not be ignored.

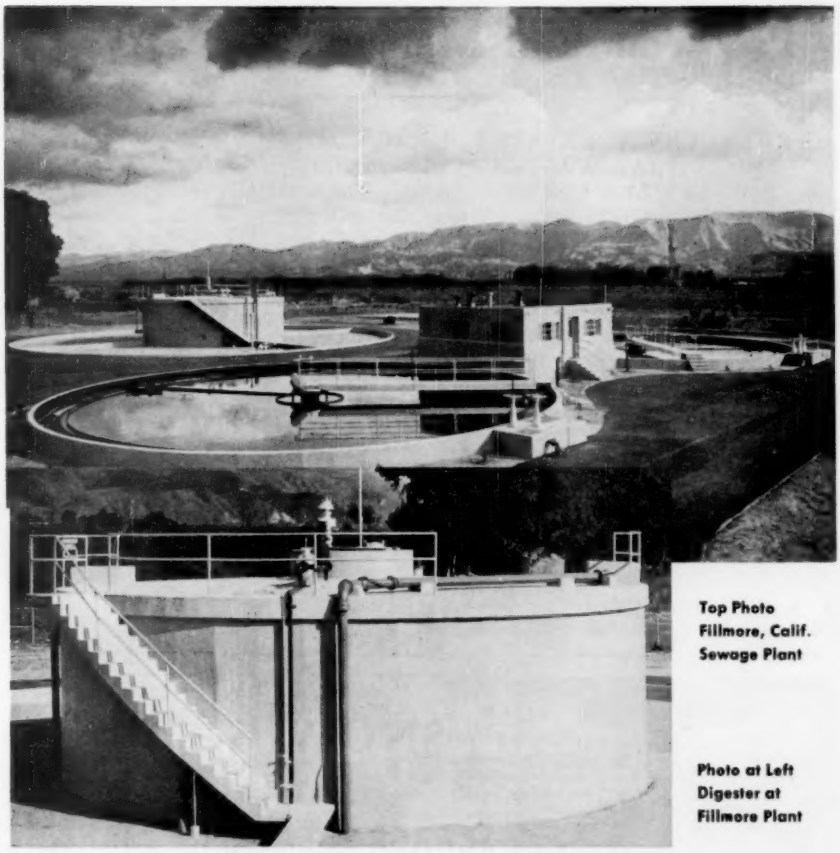
The new cover stock is white, 60-lb., coated paper. The traditional Journal blue has been retained by solid printing of the front cover and backbone. Without close inspection, the Journal will appear the same when face-up on a desk or sitting on a book shelf. Closer inspection, however, will reveal that the inside and back cover spaces are white surfaces coated to give sufficient gloss for the best reproduction of photographs or other advertising. With a white stock, the advertisers for these spaces have the possibility of using colors, a privilege which was virtually denied by the solid blue cover. To illustrate the difference, we urge you to compare advertisements in this issue with the corresponding ones of the December 1956 issue.

A further change seemed desirable for the advertising pages of the Journal and for this reason the first and last sections of the Journal will henceforth be printed on coated stock. The text will remain on the English-finish paper which the Journal has used for many years, but at some future date it is hoped that it too may be changed to coated paper. This will improve the crispness of all printing and greatly enhance reproduction of any photographs.

At first, this change would seem to be an accommodation of advertisers only, but it must be remembered that improved service to them returns dividends to all Journal readers. The change will increase the latitude of choice of advertising copy and in this way should increase the advertiser's satisfaction in his use of the Journal. At the same time, the reader will observe added display material in advertisements to keep him acquainted with the best in the sewage and industrial wastes field.

We feel that Journal readers will endorse this improvement in makeup. Also, we know reader reactions to such a change are likely to vary a great deal. Whatever your reaction may be, we would appreciate your sharing it with us.

R. E. F.



Top Photo
Fillmore, Calif.
Sewage Plant

Photo at Left
Digester at
Fillmore Plant

Varec Equipment helps Fillmore, Calif. meet its Sewage Problem

Fillmore faced a common problem of many Southern California cities, – a booming population that over-taxed the sewage system.

The solution was a compact, modern digester system that is efficient and attractive. To protect this fine plant against fire and explosion, and regulate the volatile sewage gas for smooth operation, VAREC SEWAGE GAS CONTROL AND SAFETY DEVICES are on the job.

Over 18 years of experience in controlling sewage gases has made Varec one of the leaders in the field.

Send for Varec Catalog S-3

"Varec"

THE VAPOR RECOVERY SYSTEMS COMPANY

2820 N. Alameda St., Compton, California

Cable Address: Varec Compton California (U. S. A.) All Codes

S-14 Available from Authorized Sewage Equipment Agents throughout the U.S. and Canada

Proceedings of Member Associations

KENTUCKY-TENNESSEE INDUSTRIAL WASTES AND SEWAGE WORKS ASSOCIATION

The 1956 Annual Meeting of the Kentucky-Tennessee Industrial Wastes and Sewage Works Association was held jointly with the Kentucky-Tennessee Section, AWWA, in the Patten Hotel, Chattanooga, Tenn., September 17–19, 1956. A total of 314 persons were registered.

Among the technical papers of interest to sewage and industrial wastes personnel were the following:

"Textile Waste, Recovery and Treatment," by Roy Hobart Souther and T. A. Alspaugh, respectively, Research Director and Industrial Waste Chemist of the Cone Mills Corp., Greensboro, N. C.

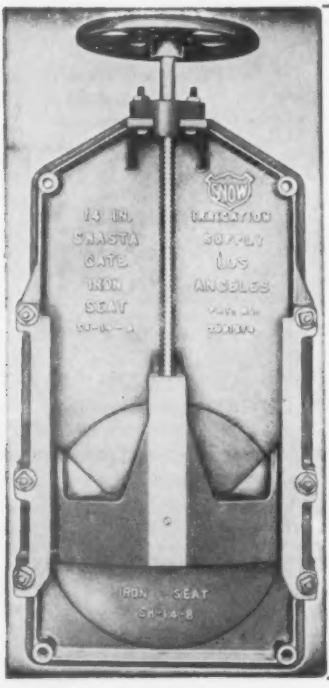
"The Stream Pollution Program of the Kingsport Division, The Mead Corp.," by John Sullins, Engineer, Mead Corp., Kingsport, Tenn.

"Theory and Operation of Separate Sludge Digestion Tanks," by Harry E. Schlenz, President, Pacific Flush Tank Co., Chicago, Ill.

"Applying Ion Exchange to Industrial Waste Problems," by C. G. Bueltman, Sales Manager, Industrial Waste Treatment Dept., Permutit Co., New York, N. Y.

"The Chattanooga Sewerage Project," by Edward S. Ordway, Partner, Havens and Emerson, Consulting Engineers, New York, N. Y.

(*Continued on page 36a*)



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SEWAGE TREATMENT PLANTS

All types of cast iron gates manufactured in either square or circular opening in sizes up to and including 72 inches.

ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

Over 40 years continuous service to the industry.

We will be pleased to quote on any type of water controlling equipment.

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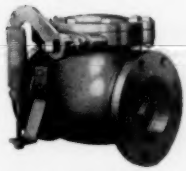
2437 East 24th Street Los Angeles 54, Calif.

Specify IOWA for every job

Iowa's complete line of valves for treatment plants assures you of efficient operation, low maintenance cost, and replacement parts when needed in years to come.



IOWA CHECK VALVES—Swing gate type for use in either horizontal or vertical pipe lines. Bronze trimmed throughout. Stainless steel hinge pins. Leather or rubber faced gates, or solid bronze, as desired—aluminum gates available for air service.

IOWA MEDIUM AND LOW PRESSURE VALVES—either non-rising stem or outside screw and yoke types. Designed as carefully as those conforming to A.W.W.A. specifications but with lighter construction for lower pressures.

Write TODAY for descriptive literature

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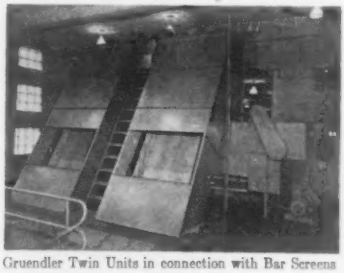

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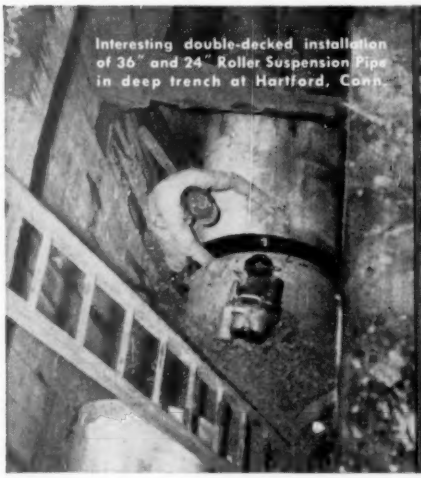
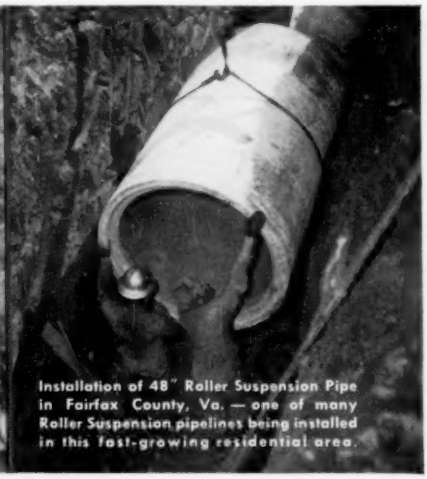


Interesting double-decked installation of 36" and 24" Roller Suspension Pipe in deep trench at Hartford, Conn.



Installation of 48" Roller Suspension Pipe in Fairfax County, Va. — one of many Roller Suspension pipelines being installed in this fast-growing residential area.

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